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THE MONTH.

THE PROPOSED COLLEGE OF SCIENCE.—Judging from the preliminary report of the committee appointed by the President of the Board of Education, it appears probable that before long an imperial seat of technology will be established in London, to co-ordinate and to supplement the valuable work now being done in various independent colleges. We must protest against the suggestion made by a contemporary that the proposed institution should be called a "Charlottenburg." There is not the slightest reason for adopting, even unofficially, a title which implies limitations of extremely undesirable character. Admirable as the teaching of the Charlottenburg High School undoubtedly is, we should make a vital mistake in copying it slavishly. The special needs of this country must be adequately recognised, and in the endeavour to meet them properly, we may consider what is being done in Germany, in France, in America, and elsewhere. The next thing will be for the best qualified judges in this country to decide what shall be accepted from abroad as a supplement to our own system of teaching. Then we may hope to see the formulation of a scheme worthy of the nation and the empire, and one that may serve as a model for the world. No detailed scheme is proposed in the present document, and it is not likely that anything will be done in this direction until the final report has been published. Some suggestions may then be expected as to the main features and character of the new college.

THE DISTRICT RAILWAY FLOOD.—Engineers who are interested in the equipment of electric railways, or in the electrification of steam railways, have before them a useful object-lesson in the effects of the flood which took place on the day selected for the inauguration of electric traffic on the Metropolitan District Railway. It has been well known for many years past that this line is subject to flooding during heavy rainstorms, and although the new pumping station of the London County Council promised to avoid such consequences, events have prove its insufficiency. If the engineers responsible for the adoption of the third-rail system on the District Railway relied absolutely on the pumping station for protection they must be possessed of a child-like faith which is not suitable in connection with the design of engineering works The third-rail system is perfectly safe in watertight subways, such as those of the Central London Railway, but in tunnels to which storm water can gain access as on the Metropolitan and Metropolitan District Railways, an overhead system of transmission is clearly advisable. It would be interesting to hear what the London County Council have to say relative to the failure of their pumping station to clear the rainwater sewers, and

also what justification the consulting engineers of the railway have for the adoption of a system of traction exposing the line to serious interruptions of traffic.

THE LIVERPOOL DOCK EXTENSIONS.—In the decision of the Mersey Docks and Harbour Board to ask Parliament for powers to expend more than £4,000,000 on the improvement of the port, London should surely find an example worthy of imitation. Among other works included in the Liverpool scheme are the provision of two river entrances, the construction of a river wall from the northern entrance enclosing the foreshore at Seaforth, the building of three new deep-water docks suitable for the accommodation of vessels 1,000 ft. long, and the erection of extensive double-story transit sheds 150 ft. wide. The authorities know that continued increase of the shipping returns can only be maintained by further accommodation, and they are by no means oblivious to the fact that steamers of far greater dimensions than those now using the port will be built in the near future. The project is one deserving of every support, especially in view of the determined efforts being made by foreign countries to secure larger shares of the world's shipping.

REFUSE DESTRUCTORS IN THE UNITED STATES.—Referring to some British criticism, the *Engineering News* admits that the backwardness exhibited in the United States destructor industry is largely due to political influence and mismanagement. Our contemporary suggests as a sort of set-off, that refuse "reduction" systems have been carried to a high state of mechanical development. Still it is again compelled to recognise the fact that reduction plants have been the cause of even worse municipal scandals than refuse furnaces. So far as reduction is concerned, this process is clearly insanitary as it involves the sorting of refuse at the works. The raw material is then cooked and separated into rubbish, water, grease and fertiliser-operations which cannot be conducted without creating some nuisance. From the economic standpoint, the reduction system is far behind the method of complete destruction practised in Great Britain.

TESTS OF CONCRETE COLUMNS.—Some records of tests upon plain and reinforced concrete columns by Professor McCaustland, of Cornell University, form a useful contribution to existing knowledge with regard to concrete-steel. The columns tested were 40 in. long by 10 in. diameter, and the concrete was mixed in the proportions of one part Portland cement, three parts sand and five parts broken limestone. The concrete-steel columns were reinforced with eight hoops in one set of specimens, and with four hoops and eight longitudinal rods in the other set. From examination of the results for plain and reinforced columns of equal age, we find that the average breaking load for plain concrete was 115,000 lbs. per sq. in., and for the columns reinforced with hoops only the ultimate strength was 214,600 lbs. per sq. in. The hoops were equivalent to a cross-sectional area of 1·57 sq. in. of steel in the form of rods. A simple calculation shows that if steel rods of this area were stressed to the elastic limit of say 27,000 lbs. per sq. in., the combined resistance of steel and concrete would be only about 157,400 lbs. per sq. in., or 57,200 lbs. per sq. in. less than the ascertained resistance. Thus we see that the value of reinforcement applied as hoops is considerably more than it would be if used in the form of rods. The tests relating to the other method of reinforcement showed a resistance of only 157,000 lbs. per sq. in., but this comparatively low result is attributed to the fact that the rods were not sufficiently bedded in the concrete, and consequently buckled so that they did not give much assistance to the four hoops. This effect is very suggestive to the designer of concrete-steel compression members.

THE NEW ELECTRIC POWER BILL.—Brushing aside the opposition of would-be monopolists, as represented by various electricity supply companies and the London County Council, the House of Commons has decided in favour of the proposal made by the Administrative County of London and District Electric Power Company to furnish electric power at a cheaper rate than any other city in the world, including even Buffalo, which is supplied from works drawing motive power from Niagara. At the present time London possesses some sixty electricity supply works, and current is sold at the average price of *2d.* per unit. The result is that more than eight thousand industrial establishments are unable to afford the luxury of electric power. By the project of the new company, the metropolis will obtain an unlimited supply of electricity for power purposes at the rate of *½d.* per unit, a price that will doubtless have the effect of abolishing thousands of steam boilers and smoky chimneys, and of encouraging numerous industries conducted on a small scale by men who cannot lay

down costly steam plant or adopt electricity at the prohibitive rates now prevailing. Assuming the hopes of the promoters to be fully realised, the Bill will benefit manufacturers to the extent of some millions a year, and at the same time effect a very important diminution of the smoke nuisance.

ELECTRIC LAMPS AND COLLIERY EXPLOSIONS.—The opinion is very prevalent that incandescent lamps give off very little heat and can be used in collieries with perfect safety. That this view is erroneous has been convincingly proved by practical experience. In a paper read before the North of England Institute of Mining and Mechanical Engineers, Mr. Holliday stated that after a fire in his colliery, he made experiments which confirmed his suspicion that electric lamps were the originating cause. The experiments of Mr. Holliday were afterwards repeated by Mr. Hall, one of H.M. Inspectors of Mines. It was then found that when a 16 c.p. lamp rested upon coal dust heat was generated with great rapidity. In one case, with a slight covering of dust the temperature rose to 370° Fahr. in three minutes, and to 450° in four minutes, when the lamp exploded. In other experiments temperatures as high as 650° Fahr. were reached, and in some cases the coal dust in which lamps had been placed was found to be red hot for some time after the original source of heat had been removed. These investigations are sufficient to suggest that great care must be displayed in the use of electric lights underground, and a fatal explosion of firedamp which took place last month in the Gendebien Colliery near Charleroi, owing to the bursting of an incandescent lamp, shows that the danger is one that cannot be overlooked.

THE LIÉGE MEETING OF THE INSTITUTION OF MECHANICAL ENGINEERS.—In the present day it is becoming quite the fashion for scientific bodies to hold their summer meetings abroad, a practice that does not invariably suit the convenience of members. In selecting Liége as the headquarters of their annual meeting, the Institution of Mechanical Engineers certainly offered facilities for the collection of much useful information relative to the industries of a neighbouring country, and for visiting the International Exhibition organised in the industrial capital of Belgium. It must be admitted, however, that the discussion of the papers read proved most disappointing, partly because the temptation to sit in a hot room for two or three hours was not overpowering to people anxious to make the best of fine weather, and partly because Belgian visitors found it somewhat difficult to follow the remarks of English members. The real value of the function was represented by the visits to the Engineering Works of the Meuse Valley, Brussels and Antwerp.

BLAST FURNACE GAS PURIFICATION.—The gases escaping from a blast furnace not only contain dust which is injurious in the Cowper stove, but water vapour and inert gases which seriously impair the calorific value of the gas. Owing to its high temperature, blast furnace gas cannot be efficiently purified by centrifugal fans, even when used in conjunction with water injection. The elimination of vapour and with it most of the undesirable substances present, can best be accomplished by cooling the gas, from the initial temperature down to about 20° C. It is then in a condition suitable for treatment by the centrifugal method. In a communication to the International Congress of Mining and Metallurgy, at Liége, M. Emile Bian described a gas cooling apparatus consisting essentially of a metallic chamber containing a number of revolving screens partly immersed in water which is continuously renewed. The gas entering the chamber at a high temperature passes through the screens, which are more or less covered by films of water. After passing several films the gas is so far cooled that the water vapour is deposited, carrying with it dust and CO_2 in solution. On emerging from the chamber the gas is cold and deprived of most of its impurities, and treatment can be completed by centrifugal or other purifiers. This apparatus is certainly designed on rational lines and should be a valuable auxiliary to the blast furnace.

PROGRESS IN CONCRETE-STEEL.—Several papers read during the past month serve to show that concrete-steel is being taken up in a serious manner. At the meeting of the Association of Municipal and County Engineers, Mr. P. H. Palmer, M.Inst.C.E., endeavoured by a paper of descriptive character to interest municipal engineers in a method of construction which he believes will be in very general use before many years have passed, and Mr. A. R. Galbraith contributed a useful discussion of reinforced concrete piling. At the meeting of the British Association of Waterworks Engineers, one of the leading features was the communication by Mr. E. Devonshire, describing the construction of a concrete-steel covered reservoir, in which expanded

metal was largely employed as reinforcement. The discussions evoked by the above mentioned papers gave ample evidence of awakened interest in the new material of construction. We may also mention as a sign of the times, the contribution of Mr. E. Noaillon to the proceedings of the Institution of Mechanical Engineers on some characteristic applications of concrete-steel in Belgium. Unfortunately, most of the authors mentioned confined themselves to description, a method of treatment quite appropriate to an illustrated magazine, but not very helpful to engineers requiring guidance in the practical design of structures.

A Proposed Central House for Engineering Institutions.—Two independent suggestions have been made during the past month that the principal engineering institutions should enter into closer relationship by the establishment of a central headquarters. The writer of an article in *The Times Engineering Supplement* points out the economic and utilitarian aspects of the question, while *Engineering* is more concerned with the advantages which the whole profession would secure by the foundation of a joint home worthily representing engineering science. The idea is by no means new, but the present time is very suitable for its discussion, because it will shortly become necessary for the Institution of Civil Engineers to provide themselves with a new building. From every point of view a joint house would be advantageous. It would afford accommodation for the meetings and the libraries of different institutions, the members of which would be brought into more frequent association than now occurs, thereby breaking down the barriers which exist to some extent between the different branches of the profession. Whether the project will ever become the subject of serious consideration depends very much upon the attitude of the Institution of Civil Engineers. That association is controlled by a sort of family party, consisting of men who are no longer young, and are not likely to favour so democratic a proposal, however pleasing it might be to the members at large. Assuming all the other institutions were prepared to incur their share of the heavy outlay necessary for building and equipping a grand central house, they would still require full recognition of their distinctive features and importance. This might raise another difficulty, because the Institution of Civil Engineers professes to cover all branches of the engineering profession, and might object to any programme likely to give it the appearance of representing one particular department of work.

Motor Fishing Boats.—In a note last month we referred to the contemplated employment of motor fishing boats in the Scotch fisheries. An experimental boat fitted with the Dan type of motor has now reached Aberdeen. This vessel has been introduced for the purpose of improving the fisheries, the idea being to ascertain whether she will enable an individual crew to compete successfully with steam drifters. If this boat comes up to expectations the Scottish Fishery Board will probably afford assistance to fishermen by fitting motors to a large number of boats. Matters have certainly reached a stage demanding prompt action by British makers of small internal-combustion motors.

The Thames Steamboat Service.—Since their appearance in regular service the new steamboats of the London County Council have been the subject of somewhat severe criticism. It has been alleged that the boats are unsafe, badly designed, and difficult to handle. With regard to the first point, we may at once say that there is not the least reason for doubting their stability. All the boats have been built by thoroughly competent firms, and have passed severe tests in a satisfactory manner. Animadversions on the design of the steamers come chiefly from people given to rowing, and who think the wash is excessive, probably because the river has been comparatively free from passenger boats during recent years. The apparent difficulty of handling at the landing stages may disappear when the peculiarities of these boats have been thoroughly mastered. Premature criticism of new things is always to be deprecated, and in the present case we prefer to defer judgment. In spite of many expressions of disapproval in the Press, the boats are being well patronised by the public, but what will happen during the winter months remains to be seen. We are inclined to believe that the traffic will be so small in volume as to lay a very burden on the shoulders of the ratepayer. Of course the County Council do things in their own way. Instead of adopting handy little screw steamers such as those doing excellent service in Paris and other Continental cities, they have provided large paddle boats, which are far less pleasant for passengers, and waste much more time at the landing stages.

Utilisation of Tidal Power.

By JAMES SAUNDERS, A.M.Inst.C.E.

THE report of the Royal Commission on Coal Supplies has made it clear that in the future England will have to generate power by other means than from coal if she is to keep her place as the foremost manufacturing nation in the world. It is true there is no immediate hurry for this seeing that there is an estimated quantity, in the proved and unproved coal fields of the country, of about 140,000 million tons of that fuel yet to be mined. The present annual output is about 230,000,000 tons, and for the last thirty years the average increase in the output has been 2½ per cent. per annum. If the same rate of increase continues in the future, in four hundred years our available coal supply will be exhausted, but long before this time arrives—if coal is to remain the only means of generating power, heat, and light—this country will be dependent on other markets, and the price of coal will prevent us from being a competing nation for the world's commerce.

The discoveries and inventions that have taken place during the preceding century leave no doubt that some force of nature will be adapted and made subservient to man's dominion, so soon as the pressure of the enhanced price of coal is felt.

The sources of power within the bounds of possibility of utilisation at the present time appear to be waterfalls, direct heat of the sun, the interior heat of the earth, and winds.

In the British Isles, according to Professor Forbes, there are only a few places where over a 1,000 horse-power can be developed from waterfalls, and he estimates that the total saving in coal which might be effected by the use of all our available water power to be about 1,200,000 tons per annum, which is equal to about 150,000 horse-power working ten hours per day. At the present time there is about 12,000 horse-power being generated by hydraulic electric plant in England.

The utilisation of the direct heat of the sun cannot be successfully carried out in this country owing to the climatic conditions, and at the present time there is no possibility of the interior heat of the earth being utilised. The largest wind-power generator in existence does not exceed sixty horse-power, and energy derived from this source is so uncertain and fluctuating that it is hopeless—until a cheap means of power storage is invented—to utilise this force so as to be of any great advantage to the community.

There are a few small schemes for the utilisation of tidal power in existence in the British Isles, the plan generally adopted being to impound the rising tide in a pond or reservoir, and, on its ebb, utilise the power by water-wheels. This does not give a constant power, and is only available during the ebb of the tide, thus making the hours of work governed by the lunar instead of the solar day. There is no doubt that this would be a serious obstacle to the success of any scheme if it could not be overcome. M. Decœur, a French engineer of some repute, has propounded a system which overcomes this difficulty to a great extent, and the following schemes are an attempt to adapt his principles to three places in this country.

Before discussing the schemes in detail it would be as well to look into the question of rise and fall of tides upon our coast. The tidal fluctuations are governed by the moon. On the west coast of Ireland and the south coast of England the highest tides occur three transits after the new and full moon, and along the east coast of

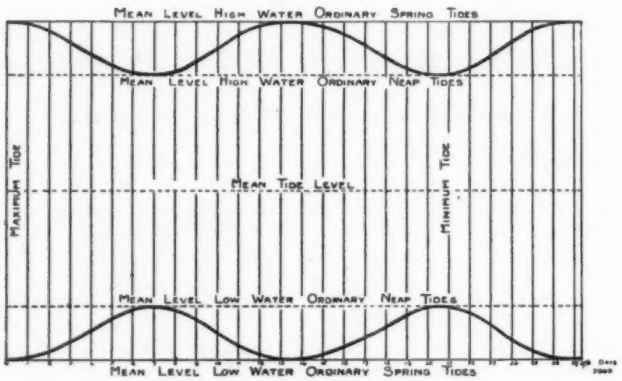

Mean Level High Water Ordinary Spring Tides
Mean Level High Water Ordinary Neap Tides
Maximum Tide
Mean Tide Level
Minimum Tide
Mean Level Low Water Ordinary Neap Tides
Mean Level Low Water Ordinary Spring Tides

FIG. 1.—DIAGRAM SHOWING VARIATION IN HEIGHT OF TIDES.

England they take place four transits after the new and full moon, and in the river Thames five transits occur in the same epoch; these times being regular unless diverted by gales of wind or other extraordinary causes.

The period that elapses between the tides is about twelve hours and twenty-four minutes, and as the moon takes twenty-seven and one-third days to travel round the earth, there are two points, one when it is in a line with the sun, and the other when on the opposite side of the earth to the sun, that the tides are at a maximum, the points equally distant between these times being the places when the tides are at a minimum, as shown in Fig. 1. The height of the tides varies considerably along the coast, being greatest on the Bristol Channel, where they have a maximum elevation between high and low water of fifty feet, and the following table gives a few of the places upon the coast of the United Kingdom showing the rise in feet at spring and neap tides:—

Place.	Springs. Feet.	Neaps. Feet.
Penzance	16¼ ...	12½
Plymouth Breakwater	15½ ...	12
Cowes	12½ ...	9½
Selsea Bill	16½ ...	12½
Folkestone	20 ...	16½
London Docks ...	20¾ ...	17½
Yarmouth	6 ...	4½
Spurn Point	18¾ ...	15
Tyne River entrance ...	15¼ ...	10¾
Aberdeen	12 ...	10
Glasgow	11¼ ...	9½
Morecambe	27 ...	21
Falmouth	16 ...	12
Portland Bill	9 ...	6½
Southampton	13 ...	9½
Brighton	19¾ ...	16
Dover	18¼ ...	15
Harwich	12¾ ...	10½
Boston deep	22 ...	15½
Scarborough	15¾ ...	12½
Queen's Ferry	18 ...	14
Oban	13 ...	9½
Douglas	20¾ ...	16
Liverpool	27½ ...	20¼
Aberystwith	14¼ ...	10
Portishead	42 ...	33
Newport	38 ...	29
St. Ives	21 ...	15

To utilise this variation of height between high and low tide it is necessary to enclose a considerable area of tidal water, which must again be divided into high and low water basins. This, of course, under ordinary conditions would be extremely expensive on account of the necessity of building massive dams to enclose the areas; therefore if a financially successful scheme is to be undertaken, the natural configuration of the coast must be taken advantage of, so as to reduce the cost of building the dams to the least possible amount. This is well illustrated by Fig. 2, which shows a tidal scheme for Chichester harbour, and it will be seen

that by building a main dam across the entrance to the harbour, 1,300 lineal yards in length, 7,380 acres of tidal water would be impounded. This dam should be of almost breakwater proportions, as shown in Fig. 3, and to admit the tidal water into the high water basin, and discharge it from the low water basin, large sluices worked from the power house by means of electric motors should be erected, so that the operator in charge could regulate the admission and discharge of the tidal water, the height of which would be constantly under his observation by means of a tidal gauge fitted on the switch-board. The dam should also be provided with locks having sea gates in addition to the ordinary gates, each of the locks being of sufficient capacity to admit the largest vessels likely to use the harbour. The dam could be cheaply constructed in cement concrete; a clean shingle, very suitable for this purpose, being readily obtainable on the harbour bar for the cost of dredging.

The harbour would be divided into nearly two equal halves (one being the high water basin, which would be filled by the rising tide, and the other the low water basin, emptied on the ebb tide), by a powerhouse and a dam, a portion of which could be constructed in a somewhat similar manner to that shown in Fig. 3, a further portion of a design as shown in Fig. 4 being formed of excavated materials from the low water basin protected by means of a concrete facing.

Fig. 5 is a plan of the main dam across the entrance to the harbour, showing the locks and power house, and Fig. 6 is an elevation of the same—the vertical and horizontal scales having a ratio of 10 to 1 respectively—showing the position of the sluices on the face of the dam. A section through the power house is shown in Fig. 7, and it is suggested that quadruple turbines, each 800 e.h.-p., should be installed, driving directly three phase alternators, but these details of the electric hydraulic plant will be discussed in a general manner further on in this article.

The power that could be obtained from this installation at the lowest neap tides would be 6,800 e.h.-p. per day, constantly for the whole of the 24 hours, in addition to this during the spring

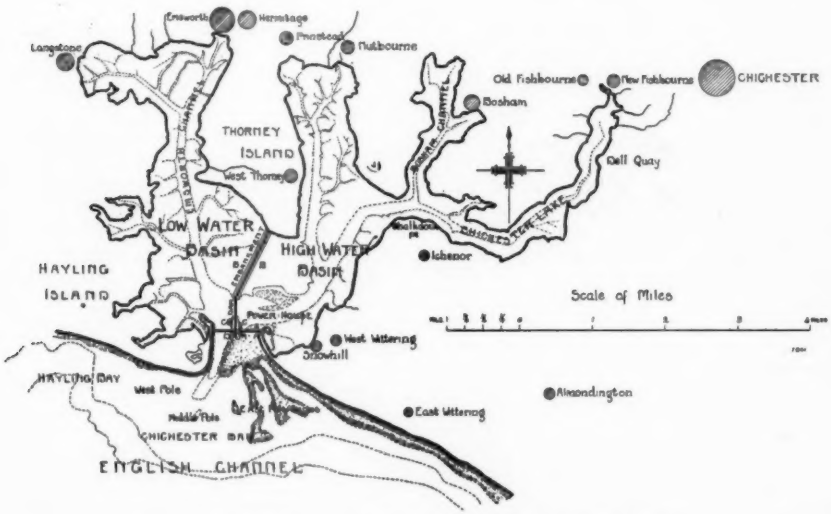


FIG. 2.—PLAN OF CHICHESTER HARBOUR, SHOWING TIDAL POWER SCHEME

C 2

Top of Dam
Stoney Sluice worked by Electric Motor
H.W.O.S.T.
H.W.M.T.
Highest level of Water in High level Basin
Lowest level of Water in High level Basin
Highest level of Water in Low level Basin
L.W.O.S.T.
L.W.M.T.
Lowest level of Water in Low level Basin

FIG. 3.—SECTION THROUGH DAM, A A.

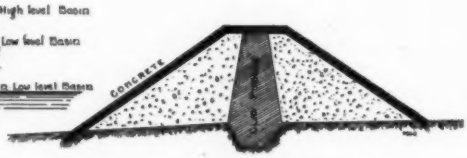


FIG. 4.—SECTION THROUGH EMBANKMENT AT B B.

CHICHESTER HARBOUR TIDAL POWER SCHEME.

tides there would be at the maximum an additional 7,000 e.h.-p. for 10 hours per day, the time that this would be available being governed by the lunar day, so that on the average there would be about 8,000 e.h.-p. per day to be disposed of.

It may be fitting to here enquire as to what is the worth of this power. The Niagara Falls Power Company, after a very careful consideration of the subject, came to the conclusion that 24 hours' steam horse power is not produced anywhere in the world for less than £5 per year, and that this price does not represent more than one-half of the total cost of the production of power. This would practically mean that, allowing for loss of power through the inefficiency of the machinery, an electrical horse power would be worth about £7 per annum. The County of London and District Electrical Power Company are proposing to supply works using power for eight hours or over per day at the rate of 0·865*d*. per unit; this for a working week of 50 hours amounts to £9·4 per annum. The two most economical electrical power stations in the United Kingdom are Glasgow and Newcastle-on-Tyne, and the following table shows the cost in pence per unit of current generated:—

	Glasgow.	Newcastle-on-Tyne.
Coal	0·15	0·16
Oil	0·03	0·02
Wages	0·13	0·13
Repairs	0·10	0·13
Total costs ...	0·41*d*.	0·44*d*.

Taking a 24 hours' day of the most economical of these stations, the total works costs amounts to £14·9 per e.h.-p. per annum, and for coal alone the cost is £5·475.

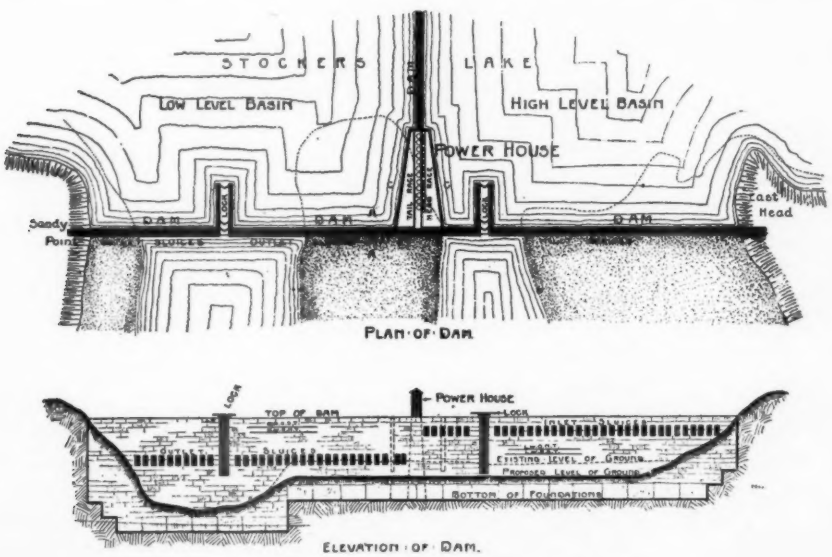
In hydraulic electrical stations the power can be produced in some cases to sell as low as £2·4 per e.h.-p. per annum, and at Niagara, according to Professor Forbes, power is being supplied at the rate of £3·6 per e.h.-p. per annum, on a capital outlay of £45 per e.h.-p., or at the rate of 8 per cent. on the outlay, which includes working expenses and capital charges. This small charge is not to be wondered at when it is known that the operating expenses on 45,190 e.h.-p. did not exceed £25,000 per annum for the whole of the output.

If £4·5 were charged per annum per e.h.-p. for a 24 hours' day, in this country it must be considered a reasonable price, in view of the foregoing particulars, and it would be much less than any manufacturer can now produce steam power for. Speaking generally, it has been ascertained that hydraulic electrical power schemes are a financial success where the interest, depreciation, working and maintenance expenses do not exceed 12 per cent. of the capital expenditure. Therefore the schemes dealt with here will be judged on this basis.

Reverting again to the Chichester harbour scheme, this gives for an average output of 8,000 e.h.-p. a yearly income of £36,000, which would justify a capital expenditure of £300,000.

A scheme for utilising the fluctuation of the tides in the Menai Strait has

several advantages over the preceding scheme, and is shown in plan by Fig. 8. Firstly, there is a variation in the height of the tides at Beaumaris and Carnarvon Bar, the points selected for the entrance and emission of the water. At Beaumaris the rise of the spring tides is 23 feet and at the neap tides 16½ feet, and on Carnarvon Bar the rise is 15¾ feet at springs and 12 feet at neaps. Secondly, there is also a variation in the time of high water at each place amounting to about an hour. Fig. 9 shows a diagram of the neap tides plotted out to show both the admittance of the water into the high level basin and the discharge of the same from the low water basin. On this diagram the dotted line A. B. shows the point of minimum fall, which is 7 feet, the maximum fall being at C. D. of 11 feet in height, the average fall throughout the tide being 9 feet, the shaded portion of the diagram showing the fall available at all periods for the production of power. The area of the enclosed basin is 6,500 acres, and the total effective electrical horse power available at neap tides being 13,500, this being increased by a further 15,500 e.h.-p. at spring tides. There would be a dam 2,600 lineal yards long, shown in cross section in Fig. 10, to construct at Beaumaris, the dividing dam between the two basins, 890 yards long, being built at Llanidan, and at Carnarvon Bar a dam 490 lineal yards long would be built to separate the low water basin from the outer tidal water. All of these dams would be provided with locks, so that the shipping traffic in the various ports on the Strait would not be interfered with. There are in this case two small rivers discharging into the low water basin, and if the full effective power of the tidal fluctuation is to be taken advantage of, these should be diverted directly into the sea, otherwise the discharge of their contents would fill up a considerable space in the low water basin, which should be kept entirely for power purposes. On the south side of Carnarvon Bar it is proposed to dam a small portion off in lieu of diverting the streams, and utilise this



FIGS. 5 AND 6.—CHICHESTER HARBOUR TIDAL POWER SCHEME.

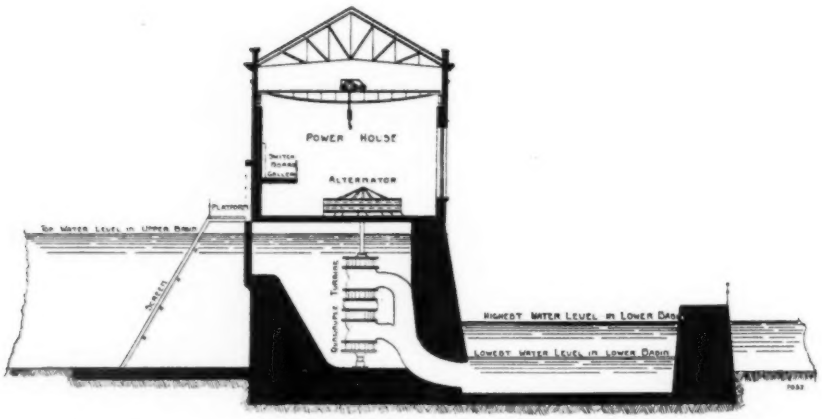


FIG. 7.—CHICHESTER HARBOUR TIDAL POWER SCHEME. SECTION THROUGH POWER HOUSE, C C.

power through turbines on the fall of the tide. The main power house is proposed to be placed on the central dividing dam, and is shown in plan in Fig. 11 and in elevation in Fig. 12. Quadruple turbines would generate the electrical energy, which would be distributed to the various towns and districts in the vicinity.

The averaged power daily available would be 14,500 e.h.-p., which, calculated of the same value as before, would amount to £65,250, a sum sufficient to pay interest, depreciation, working and maintenance expenses at the rate of 12 per cent. on a capital expenditure of £543,750. It may be questioned as to whether this amount is sufficient to erect the works under consideration, and it will be as well to go more closely into the estimates of cost of this scheme, which have been carefully worked out as follows:—

MENAI STRAIT SCHEME.

Estimate of Cost.

Lin. Yards.		£	£
2,600	Dam across Straits at Beaumaris	65	169,000
490	Dam across Straits at Carnarvon Bar ...	60	29,400
890	Dam across Straits to divide high and low water basins ...	30	26,700
	Locks	—	30,000
	Power house	—	22,000
	Sluices	—	7,000
	Turbines	—	95,000
	Alternators, switchboard, and other machinery	—	55,000
	Cable line and transformers for distribution of power ...	—	30,000
	Diverting rivers ...	—	3,000
	Promotion expenses, engineering fees, contingencies, &c....	—	75,000
	Total		542,100

A more ambitious scheme for the utilisation of tidal power is the one shown in Fig. 13, which is a scheme for the conversion into useful power of a portion of the enormous amount of energy of the tidal waters of the Bristol Channel. The Welsh grounds are proposed to be enclosed with a dam to form the low water basin, the high water basin being made by damming up the mouth of the river Severn. This has one great advantage, as the whole of the fresh waters flowing down the rivers Severn and Wye, whose combined drainage areas are about 6,350 square miles, is equal to a discharge of about 250,000 cubic feet per minute and makes a difference of 2 ft. in height to the high-water basin during the time

of its discharge. The area of the high-water basin is 23,400 acres and of the low-water basin 22,000 acres, the maximum fall available being 25 ft., the minimum fall 17 ft., and the averaged fall for the whole of the twenty-four hours being 20 ft.

This gives 240,000 e.h.-p. for the whole of the twenty-four hours at neap tides and a further 300,000 e.h.-p. for ten hours per day, available only on the ebb of the tides, during the maximum spring tides, which would be equal to an averaged daily e.h.-p. of about 21,000. It must be admitted that there is a difficulty of dealing with this semi-menstrual increase of the amount of power by any known means that would be at all economical both from a financial and engineering point of view. Briefly reviewing the means at present available for storing this surplus power and using when required, they may be put down as follows. (1) Converting the energy into compressed air, storing and reconverting to energy when required by using the same through air motors. The objection to this is the large capital cost and the great loss in the conversion and reconversion. (2) The surplus energy might be pumped up into a high storage reservoir, and afterwards the stored water be passed through turbines, thus reconverting the energy of the stored water into power. The same objections apply in this case as to the last, only perhaps not quite to the same extent, as there would not be the same amount of loss in conversion. (3) Storing the electrical energy in batteries. This would be a practical way of getting over the difficulty, but the first cost of the plant for doing this work would in all probability be so great as to financially condemn the scheme.

What appears to be wanted is a means of cheaply storing energy with a loss of efficiency on the process of conversion brought down to the minimum. It may be that a brilliant genius will some day evolve out of oblivion a process for doing this. If a simple means for the electric decomposition of water could be perfected it might meet the

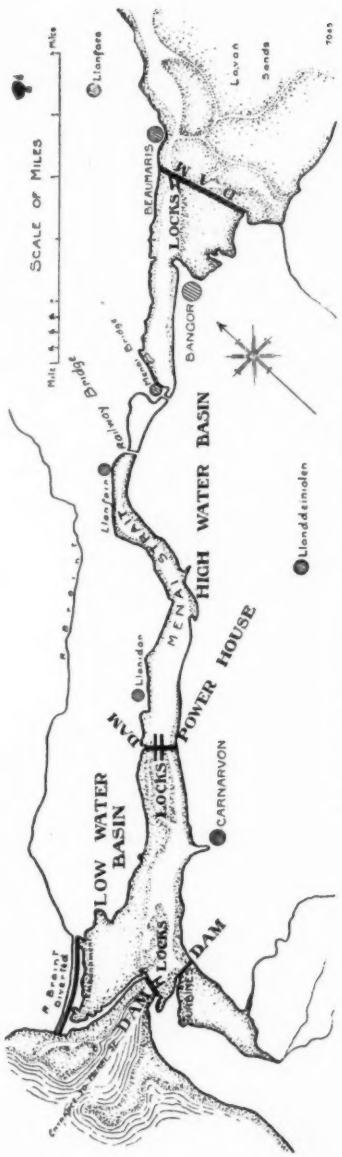


FIG. 8.—PLAN OF MENAI STRAITS, SHOWING TIDAL POWER SCHEME.

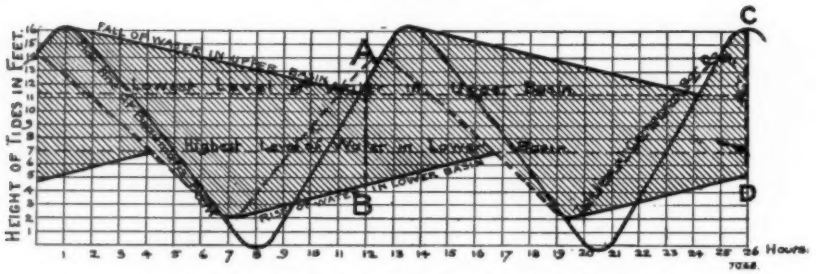
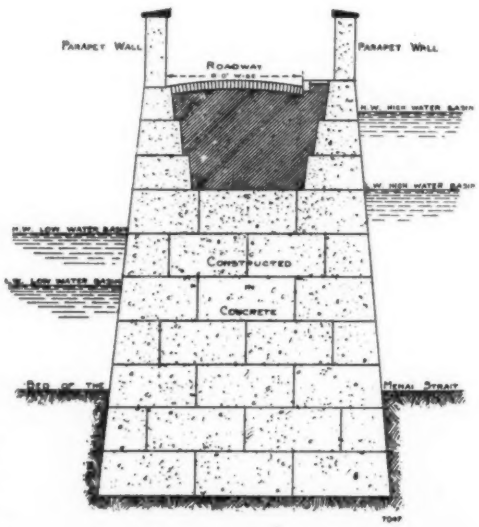

HEIGHT OF TIDES IN FEET.
A
B
C
D
Lowest Level of Water in Upper Basin.
Higher Level of Water in Lower Basin.
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 Hours.

FIG. 9.—MENAI STRAITS TIDAL POWER SCHEME. DIAGRAM SHOWING RISE AND FALL OF TIDE AND LEVEL OF WATER IN HIGH AND LOW WATER BASINS.

case, for the oxygen liberated would be available for many purposes and would be a marketable commodity, while the hydrogen would be stored in huge gas-holders and used for heating purposes. It is, however clear, that unless some advance is made on the present imperfect appliances for the storage of energy, the variable tidal flow from the maximum to the minimum of the spring tides could be made of very little use.

In the Bristol channel scheme, assuming the energy to be worth £4·5 per e.h.-p. per annum, it would realise the enormous sum of £1,170,000 per annum, which would justify an expenditure of £9,750,000.

Coming to the more general details of the work, the power-house would be placed on the dam dividing the high-water basin from the low-water basin, and means would be provided so that, during the ebb of the tide, the water from the high-water basin could be run direct into the river Severn channel without passing the same through the low-water basin, so that the fresh water coming down the Severn and Wye rivers, could be fully utilised. The dams to the high-water and low-water basins would each be designed with a sufficient number of sluices to admit and discharge the contents of the basins at the same rate that the tide ebbs and flows. It would be necessary to provide locks for the shipping traffic to the upper basin but not to the lower basin, and by doing this the shipping industry would not be materially interfered with, as at the present time in order to reach the upper ports of the Severn it is necessary to pass through a number of locks. The impounded waters of the high-level basin would form a natural dock whose rise and fall would be only 10 ft., this would materially enhance the prosperity of the ports up this part of the river, the small fluctuation in the height of the water compared with what at present exists being all to the advantage of the shipping.



SECTION THROUGH DAM

FIG. 10.—MENAI STRAITS TIDAL POWER SCHEME.

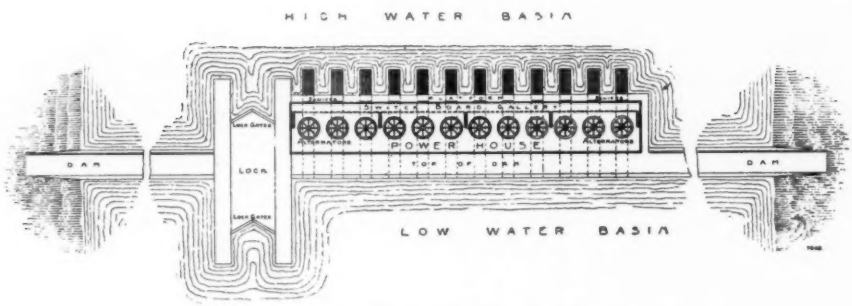


FIG. 11.—MENAI STRAITS TIDAL POWER SCHEME: PLAN OF POWER HOUSE.

The Dutch, who have had some considerable experience in damming back the waters of the sea for some centuries, have solved the problem of constructing earthen embankments for this purpose in a cheap manner, and their designs of dams could be followed with safety; but there are reasons for departing from the earthen embankment for enclosing the basins under question, and it remains to be seen whether futurity will not be able to construct a durable dam in a cheap and economical way. Figs. 16 and 17 show a suggestion on this, being the cross section and plan respectively of a portion of the dam proposed for the Bristol Channel scheme. It is proposed that the dams should be constructed in ferro concrete, the framings, which are well braced together, being all made on the land, floated out, and raised and fixed in position by means of "Titan" cranes working from the top of the portion of the embankment already finished. All that would then be necessary would be to drive in the side piles and affix the cross ties, the interior of the embankment being formed of hard excavated matter dredged from the low water basin. Such a dam should be very cheaply constructed, and could be made sufficiently strong to resist the forces brought to bear upon it.

In all schemes for the utilisation of tidal power which can be discussed at the present time, the most important point must be the question as to whether they can be made to pay or not. The success of the Niagara hydraulic installation has shown that, provided cheap power can be produced, there is every reason to believe that the enterprising manufacturers in a country will remove their factories to the vicinity, but we have now, in addition to this, the means of taking energy with very little loss of power over immense distances, so that instead of Mahomet coming to the mountain the mountain will go to Mahomet. Looking at the Bristol Channel scheme from this point of view, it will be seen that it is situated in the centre of a populous district, being able to command such towns as Bristol, Cardiff, Newport, and all the large and populous South Wales towns, as well as Gloucester, Cheltenham, Bath, and Chepstow. A district favourable for

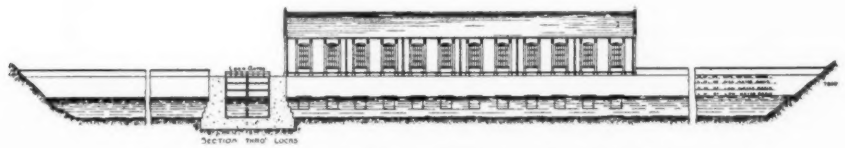


FIG. 12.—MENAI STRAITS TIDAL POWER SCHEME: ELEVATION OF POWER HOUSE.

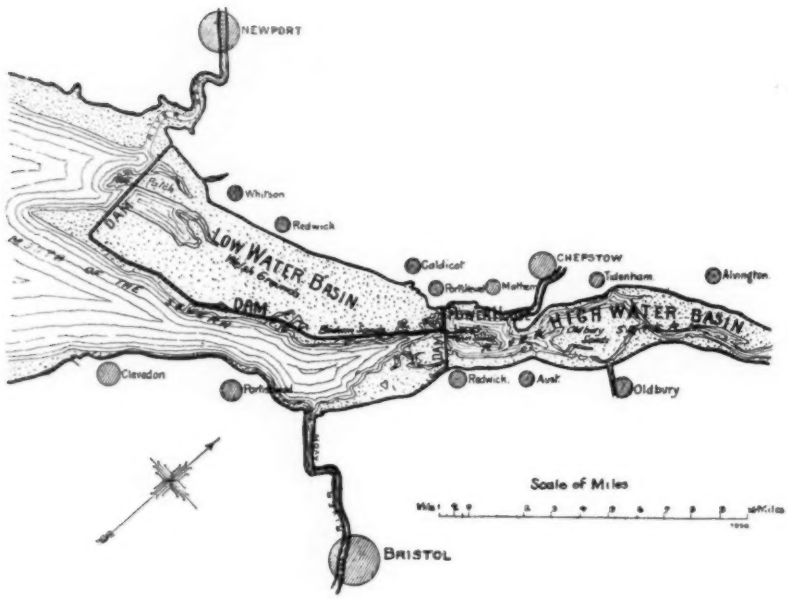


FIG. 13.—BRISTOL CHANNEL TIDAL POWER SCHEME.

disposing of energy on account of there being an accumulation of trades due to the coal fields of South Wales.

The following is an approximate cost of constructing the Bristol Channel scheme. It has been prepared without a detailed survey being made, but will be somewhere near to the actual cost, and it may be compared with what is set forth as the limiting expenditure on capital that should be made to make the scheme a financial success :—

BRISTOL CHANNEL SCHEME.

Estimate of Cost.

Lin. Yards.		£	£
32,600	Main dam enclosing low water basin...	150	4,890,000
3,960	Main dam across mouth of the Severn	150	594,000
	Locks, 1 set ...	—	50,000
	Sluices	—	100,000
	Power house ...	—	200,000
	Turbines	—	1,500,000
	Alternators, switchboard, and other machinery ...	—	1,000,000
	Cable for distribution transformers, &c.	—	300,000
	Promotion expenses, engineering fees, contingencies, &c.	—	900,000
	Total ...		9,534,000

One of the main difficulties until comparatively recent times for any scheme of this kind has been the difficulty of the conversion of the flow of the water into energy and its distribution. This has occurred because the height of the water in tidal schemes is constantly varying, the falls being low and the maximum head, compared with the minimum head, being great when considered with the height of the whole fall. Recent hydraulic installations have, however, shown us that these difficulties can be overcome, and large units, efficient both

at full head and when running at the smallest head, can be built and kept at a speed sufficiently constant to drive alternators for generating the power. It will be instructive to quote a few of these.

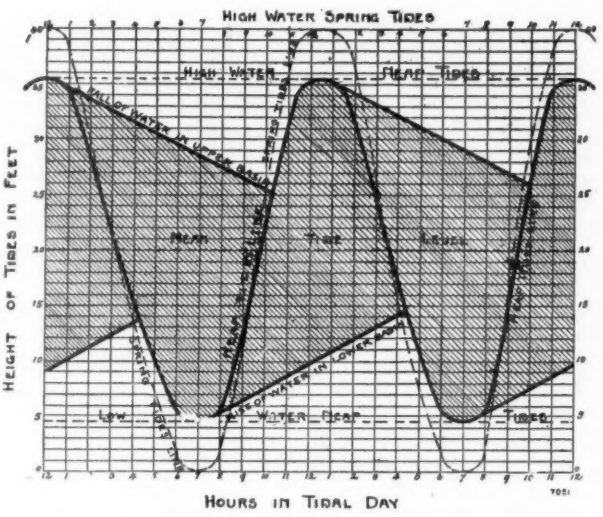


FIG. 14.—BRISTOL CHANNEL TIDAL POWER SCHEME. TIDAL DIAGRAM.

At Cusset, on the Jonage Canal near Lyons, eight double turbines each of 1,500 h.-p. are working on a fall varying from 26 to 33 ft., at a speed of 120 revolutions per minute. The turbines are directly coupled to horizontal alternators, and are regulated by means of oil pressure governors. The hydraulic electrical power station at Schaffhausen, one of the pioneer large plants erected in the world, is now well known, and under a fall varying from 11·5 to 14·8 ft., the turbines generate 350 h.-p., the efficiency at full gate being 86·6 per cent., at $\frac{3}{4}$ gate 82·6 per cent., at $\frac{2}{3}$ gate 84 per cent., and at $\frac{1}{2}$ gate 77 per cent. On the bank of the Rhine there is a large installation of hydro-electric power generating plant at Rheinfelden, consisting of twenty sets of quadruple turbines of 840 h.-p. each directly connected with the electrical generators. The speed of the turbines and generators is 55 and 68 revolutions per minute, the minimum fall being 10 ft. 6 in. and the maximum fall 16 ft. The turbines have

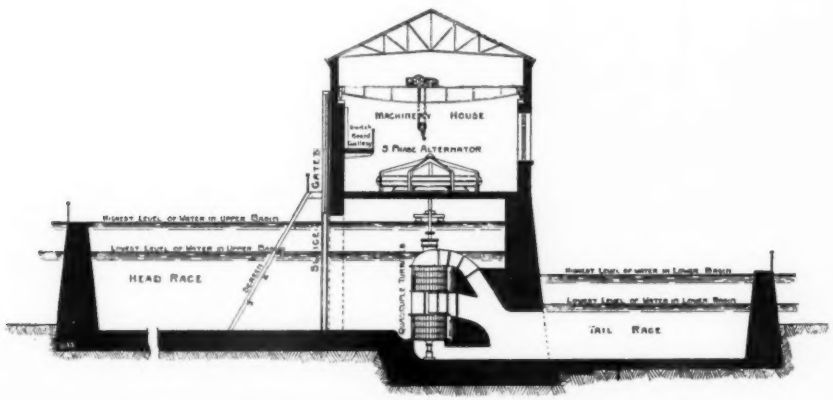
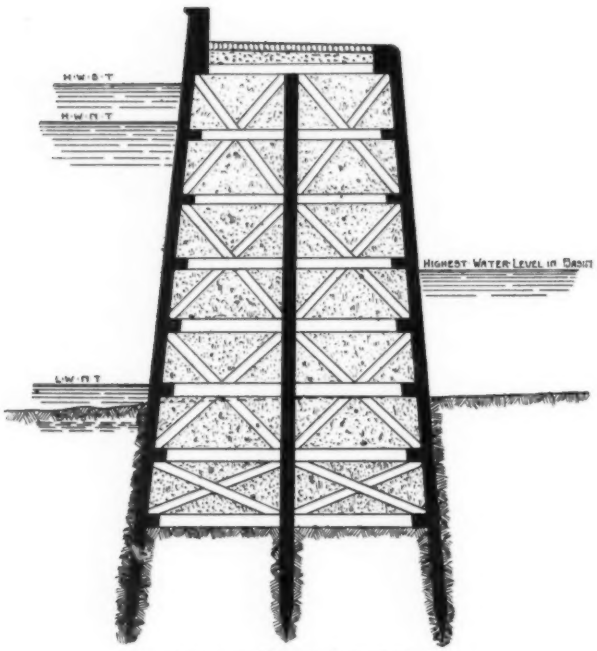
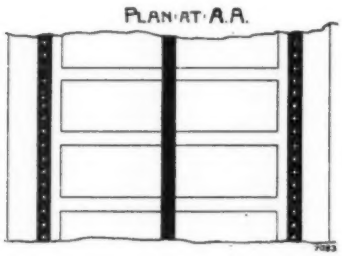


FIG. 15.—BRISTOL CHANNEL TIDAL POWER SCHEME. SECTION THROUGH POWER HOUSE.



SECTION OF FERRO CONCRETE DAM.



FIGS. 16 AND 17.—BRISTOL CHANNEL TIDAL POWER SCHEME.

a commercial efficiency of 75 per cent., and as the head of water varies so much, they have been designed so as to give a constant power. The alternators generate three-phase current at 3,800 volts, and the total losses on the power distribution plant from the turbine shaft to the factory motor has been found to be 32 per cent. An interesting installation has been erected at Chevres, where under a minimum fall of 14 ft., 1,200 B. H. P. turbines have been erected running at a speed of 80 and 120 revolutions per minute, the electrical machinery being driven direct. Five of the turbines are of the double cone pattern, and ten are designed as centrifugal turbines.

Mr. Alphonse Steiger, in a paper recently read before the Institution of Civil Engineers, stated that a large scheme was under consideration for the installation of units of 1,400 B. H. P. under a fall of 10 ft., running at 66 revolutions per minute. Considering the above accomplishments of the manufacturers of turbines, there seems little doubt that they will be able to rise to the occasion of building generators suitable for the small and varying falls obtainable in tidal power works.

Generally speaking the turbines must be designed as vertical multiple machines on the same shaft, so that the electric generators can be directly connected thereto. The speed must be kept as high as possible, but in the case of large generators it may be as low as 55 revolutions per minute, as at that speed the alternators can be driven direct.

In making calculations throughout for the three schemes mentioned herein, allowance has been made in all cases for the loss of fall in the high and low water basins, due to the sloping of the

sides of the banks, and the following efficiencies for the plant have been assumed; the turbines to have an efficiency of 75 per cent., the efficiency of the generators being taken at 90 per cent., and the loss of efficiency in distributing the current at 5 per cent.

In conclusion it may be said that the author has merely touched the fringe of the subject and tried to point out that the utilisation of tidal power is not such a phantasy as many people imagine.

There are many difficulties to be overcome before a scheme could be brought to a successful conclusion, but as the world's experience of different engineering works increases year by year, so much nearer is the time brought when light, power and heat will be generated by other means than the combustion of coal. The manufacturing city, now one of eternal smoke and vitiated atmosphere, will then become the city of health, light and cleanliness.

High Speed on Steam and Electric Railways.

By ROBERT H. SMITH.

DURING the last two or three years much has been said and written on the subject of increased railway speeds, and the popular vague idea that electricity is to make practicable hitherto unimaginable travelling speeds, since it has actually already produced many things that were unimaginable only a few years back, has infected not a few of our leading electrical engineers. Just recently there has, however, been a lull in the discussion of the main railway problem, as is well illustrated by the particularly cautious reticence in Col. Crompton's reference to it in his James Forrest Lecture. He expressed three opinions in reference to this matter, namely, that single-phase current is the only form of electric energy that may have a main-railway future before it, that goods traffic cannot be worked electrically in economic competition with steam traction, and that steam locomotive engineers are likely to greatly improve their machines as soon as there is any serious probability of electric rivalry.

Meantime electrical enthusiasts are gradually learning the general conditions and difficulties of the main-line problem which they propose to attack. A study of these, of which tramway and urban railway work has given them no experience, is necessary for success. A good deal may be already definitely and usefully said as regards the comparison between steam and electric power for high railway speeds.

It must obviously be conceded by all that electric traction has actually raised mean travelling speed upon tramways and upon city passenger railways, and in a very marked degree. Of course, electric traction on such lines has brought with it many other superior conveniences, besides higher speed, which have very largely contributed to their popularity and financial success; but the increase in speed is undoubted and important. But the increased speed is still quite a low speed. On tramways no high-speed could be permitted for reasons of public safety. On city railways doubling the present maximum speed would raise the mean speed by only so small a percentage as would yield no profit on the extra cost. The success of the electrification of such lines, in so far as speed is concerned, depends (1) on the density of the traffic; (2) on the uniformity of the service demanded, it being all local passenger traffic and there being no passing of trains devoted to ordinary, express, and goods services; (3) on the very regular and short distances between stops; and (4) upon the regular and very small time interval between trains.

None of these conditions apply to long distance express travelling. Hence it has long since been recognised that this latter problem is an entirely new one absolutely distinct from that already successfully solved on numberless short distance lines. Although Col. Crompton did not actually say so, it is to be presumed that his remarks applied only to long distance runs with either high express speed or at least mixed traffic.

It is important to note that it is only when stations are separated by long distances that very high maximum (as distinguished from mean) speed is of any practical utility, and that in these circumstances very rapid acceleration and retardation become of quite minor importance.

It is not yet certain whether very high express speed between stations far apart is or is not necessarily accompanied by long time-intervals between trains. The determination of this question is of great importance in the solution of the problem. Its determination seems to depend on two things. If it is eventually found that to work a very high-speed service it is essential to set apart isolated lines for this service alone, then this would clear the way for single-coach or two-coach express trains running at small time-intervals. The other plan of clearing the whole line of all other traffic at the times of running the flying expresses naturally leads to the opposite conclusion of making the express time-intervals long and the express trains heavy. Without arguing the matter in detail, it is obvious that the former condition of very frequent and very light express trains is favourable to electric traction, while the other is more favourable to steam traction. Thus the question of long or short time-interval depends largely upon how other conditions will determine the choice of kind of driving power, steam or electric.

Except on the basis of the idea that electricity is capable of doing for us everything that has hitherto been found impossible without its aid, it is difficult to account for the popular expectation of very high speeds resulting from electric traction. Because one of the most remarkable historical facts of the development of electric engineering is that no high travelling speeds have been attempted commercially. The Zossen trials have no flavour of commercial economy about them. If for the sake of pure scientific experiment as much money, trouble and time had been spent upon steam high-speed trials, we would by this time have learnt whether 150 miles per hour is possible with steam locomotion. The extreme maximum speeds upon commercial electric lines actually running are only half those on steam lines. So far as historic inference goes, therefore, one should not expect very high electric speeds. This, of course, is not in the least degree conclusive, since steam traction took half a century to grow up to the speeds now reached by electric traction in a life of only a quarter of a century.

The problem of very high speed is, like all truly technical problems, a complex one. It depends on certainly not less than seven factors.

The first of these is, without any doubt, the construction of the roadway. The present high steam speeds have only been reached slowly as the result of rebuilding the road-beds in doubly solid fashion, bedding the sleepers deeper and more compactly, much heavier chairs and rails, and fishplates very much stiffer and better secured. Without this reconstruction the present over-all speed of fifty miles per hour would be impossible, and it is perfectly safe to say that it could not be doubled, or, indeed, raised by any very large percentage (given the same time lost in stops) without entirely new and very expensive reconstruction.

At this first point steam and electric traction seem to be on a par: the question of kind of driving power is simply irrelevant. It may be that electric motors deal more gently with weak rails and a bad road-bed than do steam engines; but to run either at the speeds suggested would equally require rebuilding of the roadway.

This is a very important fact, because it makes it probable that for the introduction of such an entirely new kind of service the building of new and separate lines will be preferred to reconstruction of existing lines, leaving these latter for the ever-increasing local traffic. This is the more likely because for the first ten or twenty years of the new high-speed service, single track would in all probability suffice. Especially would this be so for what may be called single section lines; that is, lines with no intermediate stations between the two termini. Single track express lines between London and Brighton, between Liverpool and Manchester, between Edinburgh and Glasgow, and between

Birmingham and London seem already to offer fair chances of remunerative working. Twenty years hence very likely a dozen, or even two dozen, other similar single-section lengths might be profitably suggested. And eventually these would become, linked together, the sections of longer journeys, such as London to Aberdeen, worked upon a rigid block system.

If these considerations be correct, there is little risk in prophesying the adoption of electric in preference to steam traction on such lines. This conclusion is reached, it will be observed, without entering upon the comparative merits of the two kinds of traction *per se* beyond the characteristics already discovered and proved in tramway and city practice. It results directly from these and from the road-bed limit to speed.

The second difficulty in attaining very high speed is the air-resistance to be overcome. At slow speeds this is a small proportion of the total, and through a long range of medium speeds the air-resistance seems to rise as the square of the velocity. Above fifty or sixty miles it probably rises still more rapidly up to some critical speed not yet experimentally investigated, and not revealed distinctly by the published Zossen results. In any case, at extra high express speeds of 100 miles or over, it certainly forms the great bulk of the total resistance. In this second difficulty, again, electric traction appears to offer no direct advantages over its steam rival. With electric motors it may be easier to mould the shape of the car to that of least air resistance than with steam locomotives, but this seems the extent of the superiority that may be claimed on either side.

The hindrance to high speed which is, in the opinion of the writer, third in degree of importance, arises through the spring suspension of the cars and their under-frames upon the wheels. Under given conditions of the track, the danger of derailment at high speed depends in a very great and critical degree upon success in insulating the heavy masses lying over the wheels from the shocks arising at the rail surface, and confining these shocks to the comparatively small masses of wheel and axle. The wheels run less risk of riding over the rails in proportion to the quickness with which they are thrust down upon the rails after each such shock. This quickness is inversely proportional to the mass that must be thrust down along with the wheels. The ideal design is to have the tyres and wheel rims alone forced to follow the irregularities of the rail surface and to have everything else spring-borne. In this respect ordinary steam locomotive design is superior to that of geared electric motor tram-cars with ordinary nose-suspension. Recently there has been introduced in Switzerland and Italy a type of electric locomotive whose motor gear is coupled to the driving axles by cranks and coupling-rods. In the Ganz cars on the Valtellina line, and in the A. E. G. cars in the Zossen high-speed trials, two different forms of driving mechanism were used which are superior to that of the steam locomotive in this matter of spring suspension. Clearly the attainment of the most perfect construction as regards spring suspension is independent of the choice between steam and electric traction.

The fourth obstacle to very high speed is created by the curves on all our railways. It will be remembered that in the Zossen trials no speed above 170 kilometres, equal to 106 miles, was permitted upon the curve of 2 kilometres = $1\frac{1}{4}$ miles radius, although double guard-rails extended the whole length of the curve. Here again the whole difficulty arises from centrifugal forces which are exactly the same in steam and electric cars, except that in the latter it may be possible to keep the centre of mass slightly lower than in the former. The cure of this hindrance must depend almost wholly on the mechanical design of the roadway. On all new lines now being laid out on which important expresses are to run it is known that nothing above the smallest grade of curvature is being put in. The Langen

suspension mono-rail, as seen at Elberfeld, is a theoretically beautiful solution of this difficulty, but at Elberfeld nothing above 40 or 50 kilometres would be safe on account of the want of stiffness in the overhead track girder. This would be rectified by alteration of the design, which was probably intended for nothing over the above low-speed, but a girder to carry the suspension mono-rail safely for speeds of 100 miles or more would certainly be extremely expensive, quite independently of curvature.

In the fifth place very large boiler-power is needed on steam trains at high speed on the long runs for which alone high speed is of any utility. The record runs in the U.S.A. have been the result of mounting enormous boilers on the locomotives. It is on the boilers far more than on the engines that their practicability has depended. These big boilers, with their great load of water and coal, could only be carried after the entire rebuilding of the lines. In England our tunnels prevent us enlarging the cross-section of the boiler in any great degree. The increase of boiler weight aggravates the road-bed difficulty. Here, indeed, electric traction exhibits enormous advantage. Its cars carry no fuel, no feed-water, no store of energy in any form. Furthermore, its driving motors may be distributed over the whole length of the train, and may be applied to every carrying axle, so that the whole load may be utilised for adhesion. In spite of this, the first found decided advantage of electric over steam power, recent proposals for long-distance electric railways pile up upon the motor-car or locomotive a great load of transformers, motor-generators, accumulators, and a second set of d.c. motors.

The reciprocating action of the steam-engine is a second disadvantage for high speed. It produces oscillation, however well-balanced the reciprocating masses may be. The driving strains transmitted on the one hand through the pistons, connecting rods and crank-shaft, and on the other hand equally through the cylinders and side-frames, alternate between compression and tension, and this transmission is through a multitude of joints, at each of which there is a certain inevitable amount of weakness and pliability: at each of the working joints there is some unavoidable slack. Moreover, the joint between the axle-boxes, which are the bearings for the crank-shaft, and the side-frames is a spring joint of great flexibility. When the connecting rod is in thrust and below the centre, this spring joint opens; the vertical thrust of the connecting rod through the crosshead on the guide-bar takes part of the load off the springs. On the instroke, when the connecting rod is above the centre, the springs are again partially relieved of load because of the connecting rod pull having an upward component acting on the guide-bar. At the dead points the full load comes on the springs. The load on the springs thus oscillates twice per revolution, and the spring joint between axle and frame opens and closes synchronously. Moreover, the two side-by-side engines drive alternately on one and the other side of the machine as a whole, and a lurching motion is the unavoidable consequence. This lurching and the pitching due to variation of load on the springs—the two variations on the two sets of springs at the two sides of the locomotive differing 90 degrees in phase—are unquestionably among the chief causes of the sinuous riding which drives the leading bogie alternately on to the on and the off rail, and thus forms one serious element in the risk of derailment.

On the other hand electric motors drive by a pure torque upon their shafts, and their driving torque is uniform with almost mathematical exactitude. This is the second great item of superiority in electric driving for high speeds.

With a radical reconstruction of the locomotive steam engine, with not less than six, and preferably eight, cylinders, steam traction could, in this respect, be brought more on a par with electric driving; but the present writer does not see how it could be made equally good.

Of course a steam turbine might be substituted for the reciprocating engine, but in doing so the accompanying introduction of gearing would deprive the steam drive of the single element of superiority which we have found in its favour.

Lastly it is confidently stated that electric traction gives greater rail adhesion with the same adhesive load. Assuming this to be true, it can hardly be imagined to be due to anything else than the more uniform driving effort exerted, and to the easier spring suspension that has been commonly adopted on tramways. This must cause less jumping and less slipping of wheels on rails, the result of which is that the frictional co-efficient of "rest" is more constantly called into play in comparison with the smaller co-efficient of "motion." Whenever actual jumping on the rails takes place, it must involve the waste of a large quantity of driving energy. The importance of this difference quite certainly rises more and more into prominence with higher speeds.

If the foregoing analysis of the comparison between the two drives as suited for very high railway speeds be correct and cover the most important parts of the ground, it is to be concluded that, while the most fundamental and financially serious obstacles to such speeds are wholly, or almost wholly, unaffected by the choice of kind of driving energy and mechanism, still there are secondary, but also extremely important, differences which tell in every respect except one in favour of electricity—without transformers and without accumulators carried on board.

Steam Engine Leakage.

One of the most important—and at the same time most controversial—points in the paper read by Mr. Mellanby before the Institution of Mechanical Engineers is to be found in the conclusion that the greater part of the "missing quantity" must be due to leakage and not to initial condensation. Messrs. Callendar and Nicholson were the first to suggest the extensive character of leakage through the slide valve of an engine, and Mr. Mellanby now expresses the opinion that condensation accounts for a very small proportion of the total missing quantity. Many engineers do not accept the views entertained by Messrs. Callendar and Nicholson, apparently taking the position that as valve leakage has not received any particular attention during the last half century, it cannot be a factor of much importance in a well-conducted steam engine. Since the quantitative determinations made by the Steam Engine Research Committee, it must be tolerably clear that valve leakage cannot be overlooked, for it was then ascertained that the loss in this way ranged from 4 per cent. to 20 per cent. of the steam entering the cylinder even with well-fitted valves.

New Docks and other Public Works at Antwerp.

By
OUR SPECIAL CORRESPONDENT.

At a time when schemes for the improvement of the Port of London form the subject of frequent discussion by public bodies and all who are interested in the prosperity of the greatest centre of shipping in the world, it is well that attention should be drawn to the great extension works now in progress for the purpose of enabling Antwerp to deal more efficiently with her growing commerce. These works will also have the effect of diverting further traffic from the Thames, and they constitute one more proof of the reproach that foreign nations act while we waste precious time in mere talk.

Like London, Antwerp owed her development to the Saxon race, passed into the hands of Norsemen, was endowed with laws containing provisions akin to those of the Habeas Corpus Act in England, and, possessing freedom and security, rapidly became a great mercantile and shipping centre. Four hundred years ago, as many as five hundred vessels were known to enter the port in a single day, and two thousand five hundred ships might be seen at anchor in the river. Evil times then came, but just on the eve of the eighteenth century, Antwerp again entered on a career of prosperity. In 1803, the Emperor Napoleon, influenced partly by his excusable animosity towards this country, determined to make Antwerp a great military and commercial station, and expended fully two millions in the construction of docks and quays.

In 1875, the dock system included an area of nearly 100 acres and more than 21,000 ft. of quay space. Two of the docks built by Napoleon, now designated the Bassins Napoleon and Guillaume, were still in existence, and the others were the Bassin du Kattendyk, the Bassin au Bois, the Bassin Asia, the Bassin de Jonction, the Bassin du Canal, and the Bassin de la Campine. All these docks formed a connected series, in communication with the Scheldt and the system of inland waterways.

So great was the increase of traffic that the dock system soon required further extension. In 1881, the Bassin du Kattendyk was lengthened, in 1887-8 the Bassins Lefebvre and America were built, giving a further water area of 54 acres, and to allow for the increased draught of modern vessels the sills were made 6 ft. 6 in. lower than that of the Bassin du Kattendyk. Further dry docks were also constructed, and three small docks near the Gare du Sud.

These additions, together with auxiliary works and extensions of the quays along the river brought the dock system up to a condition not very different from that in which it is found to-day.

We are indebted to Mons. G. A. Royers, Ingenieur-en-chef de la Ville d'Anvers, for some of the details incorporated in the following descriptive notes.

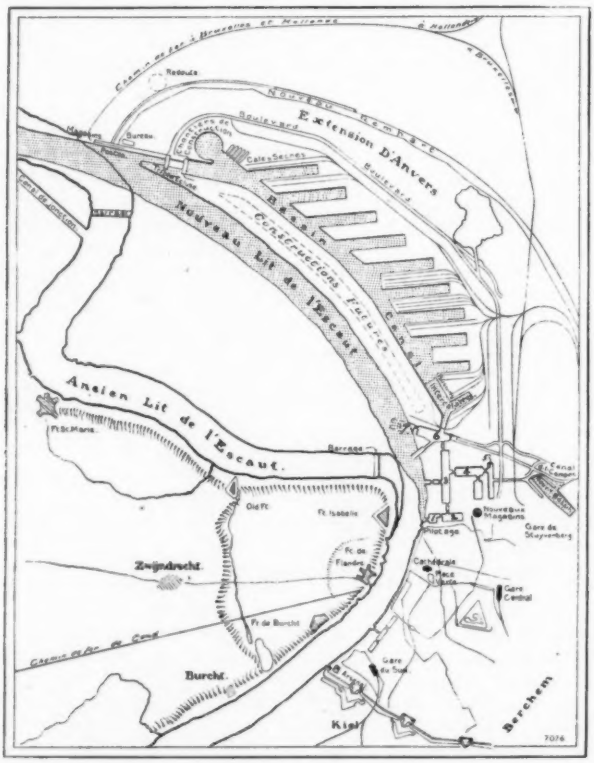
The existing quays of Antwerp at present extend along the eastern bank of the river Scheldt for a distance of nearly 2½ miles, the depth of water being 26 ft. at low water, and 40 ft. at high water. The tidal range is about 13 ft., and the quay level is about 8 ft. above mean high water level.

Extensive transit sheds are built along part of the quay walls on the top of which a fine promenade has been formed.

Between the sheds and the quay front, and also at the back of the sheds, are two or three railway lines which are placed in communication by means of turning and travelling platforms operated by electrically-driven capstans.

The quays are amply supplied with machinery for handling merchandise, the plant including one hundred hydraulic travelling cranes, of capacities varying between $1\frac{1}{2}$ and 2 tons each.

The plan which we reproduce in Fig. 1, includes the existing dock system and the projected extensions. For the sake of distinction, the new docks and other works—to which reference will be made later—are shaded in the plan, the present dock system being left plain. The whole of the dock system is the property of the municipality, and the water level throughout is maintained at about 1 ft. below that of mean high water. To the north-east of the Gare du Sud are the three docks already mentioned, these being used chiefly for the petroleum trade, and near them is the landing stage used by the fleet of the Great Eastern Railway. A little way north of the cathedral is the Chateau du Steen, the last remnant of the ancient



1. Bassin Napoleon.
2. " Guillaume.
3. Bassin du Kattendyk.
4. " aux Bois.
5. Bassin Asia.
6. " Lefebvre.
7. Bassin America.

FIG. 1.—PLAN OF ANTWERP DOCK SYSTEM.

castle, now used as a museum of antiquities. Near the Steen is a pontoon landing stage 328 ft. long by 65 ft. wide, on both sides of which jetties have been built, with railings and flights of steps.

A little further on we come to the Pilotage, where accommodation is provided for the School of Navigation, and various offices connected with the administration of the docks.

Just beyond the Pilotage is the entrance of the sluice giving access to the half-tidal Petit Bassin, one of the docks built by Napoleon, and to which the name Bassin Napoleon has lately been given. The sluice head has an opening 59 ft. wide, and the main dimensions of the dock are 490 ft. by 474 ft., but there is an extension at the north-east corner, about 80 ft. long, leading to the adjoining dock formerly known as the Grand Bassin, and now as the Bassin Guillaume. This dock, connected with the smaller basin by a sluice head with a 59 ft. opening, was also constructed by Napoleon, and measures about 1,310 ft. long by 475 ft. wide.

Some 600 or 700 yards lower down the river is the entrance to a small basin leading to the Bassin du Kattendyk, built in 1856-60, and extended in 1881 to the dimensions of 3,150 ft. long by 460 ft. wide. As shown by Fig. 1, an intermediate dock connects the Bassin Kattendyk with the Bassin Guillaume. Six dry docks adjoin the Bassin Kattendyk. The first of these, originally built in 1863, has been enlarged so as to receive vessels up to 508 ft. in length. Of the remaining dry docks three are 420 ft. long, one nearly 250 ft. long, and another 170 ft. long.

On the Eastern side of the Bassin Kattendyk there are two 40-ton hydraulic cranes and a 120-ton derrick crane, and here also is the opening leading to the Bassin du Bois, built for the timber trade and measuring 1,710 ft. long by 492 ft. wide.

The present intention is to devote one side of this dock to mineral traffic, chiefly iron ore, and for this purpose a series of hydraulic cranes of the "portico" type has been installed. An automatic coal-tipping machine has been installed on one of the quays, capable of hoisting a railway truck with full load up to 25 tons. The Bassin Asia, to the east of this dock, has a length of about 2,430 ft. and a width of about 312 ft. and is also destined for the ore and timber trades.

The northern end of the Bassin du Kattendyk communicates by means of a small basin with the Bassin Lefebvre, a dock of irregular polygonal outline. Along the northern, southern, and eastern quays extensive sheds have been built, and an excellent equipment of hydraulic travelling cranes has been provided. At the southern quay there is a 10-ton crane for dealing with timber imported for cabinet makers, and at the western side of the same quay a large grain silo, with a capacity of 120,000 quarters of wheat. The Bassin America was originally used for the petroleum trade, but since the construction of the three docks specially devoted to this class of traffic it has been used for general merchandise, and is now being re-equipped with modern machinery and appliances.

A general system of hydraulic power transmission has been installed for all the docks in this part of the city, the power station including a battery of six Cornish boilers and four steam engines of 150 h.-p. each.

At the end of the Bassin Guillaume were situated the bonded warehouses, built in 1831, which were almost entirely destroyed by the great fire of 1901. The warehouses then consisted of an extensive range of buildings in three groups more or less isolated by courtyards. The main blocks were six storeys high, and the connecting buildings four storeys and one storey high. The method of construction was extremely unsuitable for fire-resistance, wood being freely used for floors and window frames and sashes, as well as for doors in the partition walls. The total loss caused by this memorable fire amounted to more than five million pounds sterling.

After so disastrous an experience the city authorities wisely decided to rebuild the warehouses in ferro-concrete on the Hennebique system, and to use nothing but non-combustible material for the interior fittings.

As rebuilt, the warehouses cover an area of about 7½ acres and consist of four blocks, each of four storeys and completely separated one from the other.

The general details of construction, although not the arrangement, are similar to those of the new dock sheds at Manchester, described in the article on p. 905 of our last volume, and the mechanical equipment includes numerous electrically-driven cranes and lifts for handling merchandise.

The progress of Antwerp as a port is strikingly shown by the following figures :—

Year.	No. of Vessels entering.			Tonnage.
	British.	Other Countries.	Total.	
1826 ...	126	783	909	122,221
1862 ...	777	1,515	2,292	579,899
1872 ...	2,172	2,034	4,206	1,656,984
1880 ...	2,292	2,203	4,495	3,063,825
1889 ...	3,013	2,600	5,613	6,872,848
1904 ...	—	—	—	9,500,000

Owing to the continued increase of traffic, a movement has been on foot for some years past to induce the authorities to make further additions to the dock and quay accommodation. Fortunately, however, instead of having to arouse the interest and secure the co-operation of various conflicting interests and mutually distrustful public authorities, and, in addition, to obtain the approval of the Government, the advocates of extension had only to influence two bodies, the Belgian Government and the municipal authorities of Antwerp.

As soon as the corporation were prepared to move in the matter, the position was tolerably easy, one of the chief difficulties being that part of the fortifications, erected in 1860 at a considerable distance outside the ancient ramparts of the city, was in the way of the proposed works. The southern line of fortifications is partly shown in Fig. 1, the northern end running outside the Bassins America and Lefebvre, and the Canal de la Campine. As the Government continued to attach considerable importance to the military defences of the city, it was evident that the extension of the docks would necessitate the construction of a new rampart and a new line of forts. The heavy outlay involved by these works probably had a retarding influence on the negotiations, in addition to which differences of opinion have existed for some time between the Government and the municipality as to details of the port extension.

Several years ago, the Government advocated an important modification of the river Scheldt, but the city authorities opposed this, because they feared it might reduce the depth of water and so cause injury to the commerce of the port.

Pending a final settlement, new quays to the length of about 6,500 ft. were added in 1903, and the line of fortifications opposite the Bassin Lefebvre was opened to afford facilities for the construction of the Bassins Intercalaires now in course of construction and covering a total area of nearly 70 acres. These docks will cost fully £300,000 and will be completed during 1907.

Within the last two or three months all controversial points between the Government and the local authorities have been finally settled, and the joint scheme now forms the subject of a Bill which was presented to the Belgian Parliament in May last. This measure was approved by a Special Committee on June 23rd, and at the time of writing is under discussion by the Chambers. Judging by the remarks of King Leopold on the occasion of his official visit to the Liége Exhibition and by other manifestations of opinion there seems to be every reason for believing that the Bill will be duly ratified.

By reference to Fig. 1, the reader

will be able to follow the main features of the new scheme, which involves an expenditure of £4,320,000 for new fortifications and about £5,700,000 for new docks and other works, making a total of £10,000,000.

The most striking feature of the scheme is the diversion of the river Scheldt from the old bed into a new channel nearly six miles long. The arguments in favour of this diversion are that the westerly sweep of the river, commencing about six and-a-half miles on the downstream side of Antwerp, presents some dangerous bends and aggravates the hindrances to navigation by shifting sand-banks.

This section of the Scheldt will be cut-off by means of two barrages at the points indicated and a Canal de Jonction will be provided for the supply of water and as a means of communication to the enclosed area. The new bed will be carried in a direct line to re-join the river at the other end of the sweep, just opposite the present docks.

At the time when this diversion was first proposed, the local authorities feared that serious interruption to traffic would take place during the execution of the works. The project now formulated removes all apprehension on this score.

Before the deviation works are commenced a canal, officially described as the Bassin Canal, is to be made, parallel with the new river bed and placed in communication with the present channel by means of a navigation cut and a series of three parallel locks, (triple écluses) each 984 ft. long by 98 ft. wide and having a depth of 26 ft. at low water. Measuring from the lock entrance to the Bassins Intercalaires the canal will be about 4 miles long or about 4½ miles measured from the present bank of the river below the new locks. The average width of the canal will be 815 ft. and the depth 39 ft. at high water.

By the formation of the canal, vessels will be enabled to pass direct to the Bassins Intercalaires and thence into the Bassin Lefebvre and the connected system of docks, quite independently of the river between the northern bend and the city. Consequently, any temporary obstruction of the Scheldt during the subsequent cutting of the new bed and the building of the barrages will involve no serious interference with the traffic of the port.

New warehouses and berths will be provided near the commencement of the new cut, and on the north-eastern side of the Bassin Canal various docks are to be built. Near the locks a circular basin is to be formed surrounded by shipbuilding yards. Next to these will come a series of five dry docks, the largest with a length of 820 ft., and then nine open docks of which seven will be about 3,940 ft. long by 656 ft. wide with a depth of 39 ft. at high water. The other two docks of the series will measure about 3,150 ft. long and 2,110 ft. long, respectively, with the same width and depth as the others.

All these docks are parallel one with another and by having their openings at an obtuse angle with the side of the canal, they will be readily entered by vessels.

A branch from the various lines of the Belgian State Railway system will be carried round to the berths at the commencement of the new channel of the Scheldt, thus affording direct connection on one hand with Holland and on the other with Brussels and all parts of the country. Branches from the same railway system will also be taken to the nine new docks and the Bassins Intercalaires, while the quays round all the new basins will be amply provided with sidings for dealing with traffic.

The land bordering the south-western side of the Bassin Canal and the north-eastern bank of the new river channel, will be laid out with quays and as the area of this long narrow island will be more than 270 acres, it should provide an admirable site for the building of warehouses and transit sheds.

From the foregoing particulars it will be seen that on either side of the new canal there will be so much additional

accommodation for shipping, that temporary obstruction of the river during the execution of the river diversion need not cause any serious inconvenience.

After the completion of the Bassin Canal the diversion of the Scheldt will be commenced. As shown in Fig. 1, the old bed will be remodelled for a short distance below the right-angled bend below the entrance to the Bassin Canal, and shortly before re-joining the old bed opposite the existing docks, the new channel will pass through the Bassin America, which, in consequence, will be abolished.

The cutting of the new bed presents no engineering difficulties, and as soon as this work has been finished, the tortuous section of the river will be closed by the two barrages, and water will be admitted to the new channel.

As at Bristol, the endocked portion of the river will be used as part of the port and will doubtless be much appreciated as a place where vessels can lie while awaiting orders or consignments, instead of occupying valuable space in the docks proper.

The area which will become an island between the old and the new channels of the Scheldt is at present occupied by various villages and hamlets. These are to be abolished so that the land may become available for the prosecution of industries requiring access to the river and docks. At the same time, we have no doubt that the authorities have not overlooked the extreme suitability of this island, for further extensions of the dock system in future years.

The cutting of the new channel will finish an additional riverside space available for quays, and when the entire scheme has been completed the total length of quays of all kinds in the Port of Antwerp will be nearly thirty miles.

The material provided by excavation from the new works will be used for raising the level of the low-lying land around the new docks, and in providing suitable foundations for buildings to be erected.

Reference to Fig. 1 will show the position of the new fortifications (nouveau rampart) between which and the docks a handsome boulevard is to be laid out, and the remaining area will form the site of a residential quarter for those employed in the docks, and doubtless for various industrial establishments.

It is estimated that the construction of these great works will occupy about ten years, and their completion will certainly give Antwerp the premier position among the seaports of the world, unless by any happy chance those who control the destinies of the Thames should become awakened to a sense of their responsibilities and forthwith commence to regenerate the Port of London.

The Canal System.

No account of the shipping industry of Antwerp would be complete without mention of the great canal system of which it is the chief port and distributing centre. All the main and subsidiary inland waterways of Belgium, amounting in all to 1,360 miles, converge upon Antwerp, whence raw materials received from all parts of the world are distributed to the different provinces, and where they are again received in the form of finished products for redistribution. Not content with the natural advantages provided by the Scheldt, the Meuse, and other rivers, the Belgians have had the wisdom to base upon these rivers a splendid system of canals which facilitates and reduces the cost of transport, and materially aids manufacturing firms to compete with their rivals abroad.

Most of the canals belong to the State, or are under State control, and they are administered in such a manner as to give the utmost possible advantages to the industrial classes.

The barge traffic of Antwerp has assumed immense proportions. In 1902, 31,850 barges entered the port, the total measurement being 5,705,731 tons, and of these, 25,886 barges representing 3,710,813 tons were engaged in purely Belgian traffic. These figures are surpassed by the outward traffic, which was represented by 33,250 barges with a total measurement of 5,939,674 tons.

Analysis and comparison of statistics for 1882 and 1902, show that during the

twenty years in question the number of barges increased by only 17 per cent., while the tonnage increased by nearly 270 per cent., thus proving that the rivers and canals have been so much improved as to permit navigation by vessels of greatly increased size.

The Rhine barges leaving Antwerp almost every day average 250 ft. in length with a beam of from 32 ft. to 36 ft., and carry loads of 1,500 tons each. On this route express goods steamers with a carrying capacity of 500 to 600 tons are in regular service. A second route to the Rhine is by the Belgian and French canal systems, but owing to the inadequate depth of water in the German part of the Marne-Rhine canal 250 tons represents the maximum carrying capacity of the barges used for through traffic. On the Belgian portion of the route, however, the loads carried average 350 tons.

Among various improvements of Belgian inland waterways recently completed and in progress, are the deepening and widening of the Canal de Jonction de la Meuse à l'Escaut, the Maastricht-Bois-le-Duc canal, and the Liége-Maastricht canal. These waterways will have, in the immediate future, sufficient dimensions to permit the passage of 1,000-ton barges instead of the 350-ton vessels previously employed. The Antwerp-Turnhout canal and the Turnhout branch canal have also received similar attention.

Two main lines place Antwerp in direct communication with Paris, one route being available for barges of 350 tons and the other of 70 tons The Brussels-Charleroi canal, forming a part of the latter route, is now being remodelled at an estimated cost of £2,145,200, so as to take barges of 400 tons capacity.

In all, seven chains of waterways afford direct water transport between the Port of Antwerp and the manufacturing centres of Belgium, Northern France, and Germany, and another important route is that which gives direct communication with Holland. Besides these main navigation highways numerous other canals in connection with Antwerp are used, some as through routes and others for local traffic.

We have touched very briefly upon the navigable waterways of Belgium, but enough has been said to indicate their immense importance, and to suggest the desirability of similar development in our own country.

Concrete-Steel Construction.

Various other public works in Antwerp are of distinct technical interest, but we can only afford space for particulars of two representative examples of concrete-steel construction. The first of these consists of a covered reservoir recently completed by the Antwerp Waterworks Company for the new pumping station at Luythagen.

The reservoir is built with a framework of rolled-steel joists, channel and angle bars, and surrounding this framework is a layer of concrete reinforced by expanded metal. The concrete is composed of Belgian Portland cement, washed river sand, and pebbles screened so as to pass through a $\frac{3}{4}$-in. ring. The cement was mixed with twice its volume of sand to form the mortar. The aggregate was gauged and cement mortar added in sufficient quantity to fill the voids plus a margin of 10 per cent. The concrete was mixed with a minimum of water, being deposited in thin layers and carefully tamped. The expanded metal was used in wide sheets of the various lengths required to span the joists of the framework and to provide an adequate overlap. Expanded metal lathing was also used for covering the roof channel bars.

The reservoir measures 253 ft. 4 in. long by 133 ft. 8 in. wide. Its depth from floor to roof is 10 ft. 6 in., and the depth of water to the top of the overflow pipes is 10 ft. It is built entirely underground, the top of the flat roof being level with the surface of the ground. The details of construction are clearly indicated in the various sections reproduced in Fig. 2.

Owing to the fact that the soil at

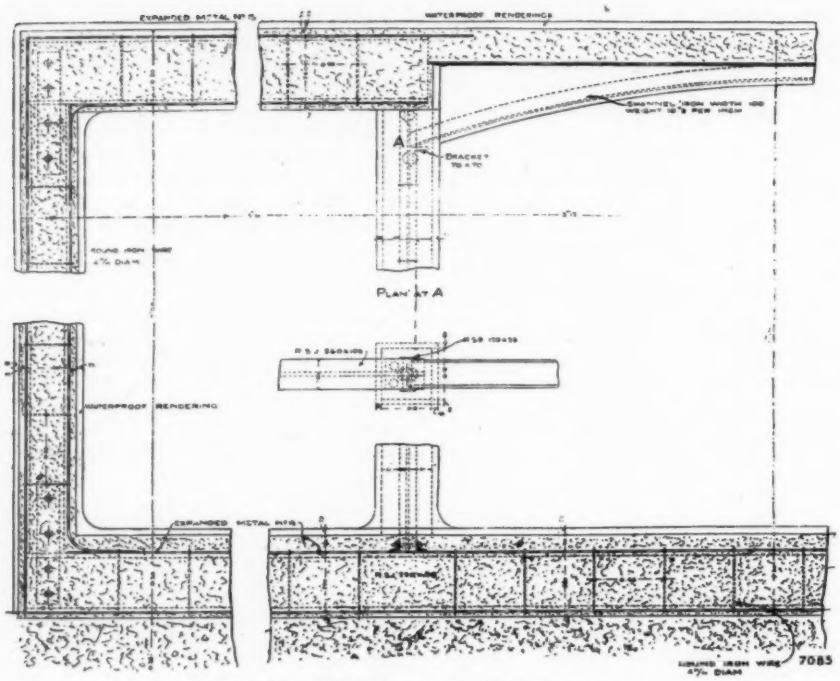


FIG. 2.—COVERED RESERVOIR, ANTWERP WATERWORKS

Luythagen is waterlogged to within 5 ft. of the surface it was necessary to employ pumps during the excavation of the site and the construction of the reservoir to keep the water down.

Excavation was carried down to a depth of 2 ft. below the level of the finished floor.

The foundation was then prepared and its surface floated in cement, the whole of the reservoir being covered with expanded metal laid in sheets 8 ft. long by 8 ft. wide, the long diagonals of the meshes being placed at right angles to the principal axis of the reservoir. The sheets overlap each other 3 in. on all four sides, and the outside sheets are of sufficient size to extend 8 in. beyond the outside of the reservoir walls. The sheets were placed so that their lines of overlap endwise were under the 9 in. by 4 in. floor joists carrying the roof columns. These joists were laid end to end in lengths of 10 ft. 5 in., being butt-jointed by fishplates and bolts. The floor joists run from east to west in parallel lines 7 ft. 6 in. apart, centre to centre, except the two outer lines which are only 6 ft. 6 in. from the side walls. The joists being laid, $\frac{5}{16}$ in. diameter steel rods were hooked through the underlying sheets of expanded metal and turned up at each side of the joists at distances of 10 in. apart. The first layer of concrete was then laid between the rows of joists and rammed through the meshes of the expanded metal. Successive layers were then spread to within 3 in. of the top flanges of the joists. Concrete was afterwards added to the height of $2\frac{1}{2}$ in. above the joists, a second layer of expanded metal sheets being placed in position as the concreting proceeded.

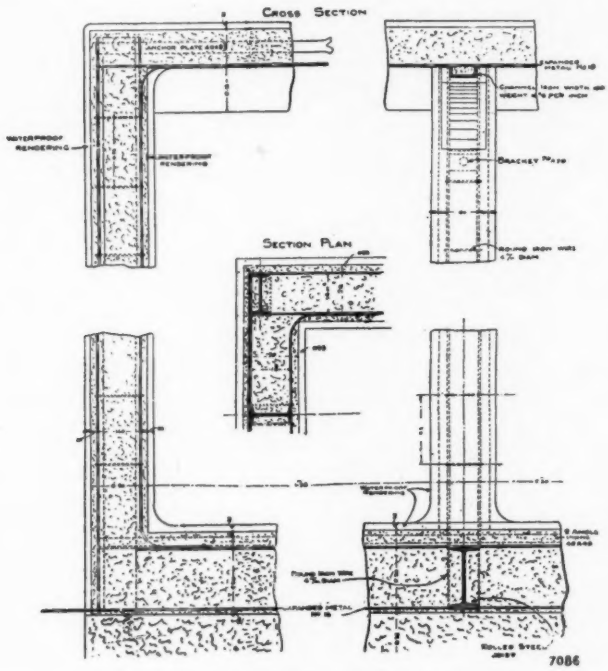


FIG. 3.—COVERED RESERVOIR, ANTWERP WATERWORKS.

The joists, forming stanchions or reinforcing cores for the columns, were placed at their proper positions on the floor girders as the construction of the floor advanced. These stanchions stand vertically on the top flanges of the floor joists, the expanded metal being cut so as to pass around them. They are held in position at the foot by angle-bar ties running from side to side of the reservoir and laid immediately over the upper layer of expanded metal. Bolts pass through these ties on each side of the stanchions, and they are buried in the concrete of the floor. At the two ends of the reservoir, the floor joists extend to the outside of the wall, and the wall stanchions standing upon them are attached by plates bolted to the web of each joist and bent so as to pass around the upper flange of the joist, thus permitting them to be bolted to the web of the stanchion. Along the end walls, stanchions are placed mid-way between those secured to the floor joists, these intermediate stanchions standing on plates buried in the concrete of the floor. The stanchions forming the framing of the side walls stand on similar plates at distances of 5 ft. 2 in. apart.

The reinforcement of the walls is formed of expanded metal sheets in three rows on each side of the stanchions, the long diagonal of the meshes being horizontal. On the outer face of the wall, the sheets are carried down to the sheets laid on the underside of the floor and extending beyond the foot of the wall. On the inner face of the wall the sheets are bent to a curve at the floor level, and are attached to the upper sheets of the floor so as to form continuous reinforcement along the angle between the walls and floor. At the corners of the

reservoir, covering sheets of expanded metal connect the vertical reinforcement of the adjacent walls both inside and outside. Along the side walls the expanded metal sheets are lapped at each stanchion, to which they are attached by $\frac{3}{16}$ in. steel rods passing round the stanchions and through the meshes of the sheets.

Along the end walls, where the stanchions are closer together, each sheet of expanded metal spans three stanchions, the ends being overlapped at alternate stanchions.

The column stanchions were erected before the surrounding concrete was added, and they were held in position by the channel bars of the arched roof and by temporary wood struts. Straps of wire were fastened round the stanchions at intervals of 10 in. apart, measured vertically, and the concrete was rammed into moulds so as to form $7\frac{1}{4}$ in. square columns. The columns are spaced 10 ft. 5 in., centre to centre, along the axis of the floor joists, and 7 ft. 6 in. apart across the reservoir.

The roof is a continuous slab of concrete $5\frac{1}{2}$ in. thick, reinforced by expanded metal at its lower face and carried on Golding arches extending from column to column. The Golding arch is formed of a channel bar 4 in. wide, filled in with concrete to the level of the slab roof, and constitutes a rib which is monolithic with the roof slab. The channel bars spring from angle brackets rivetted to the column stanchions, the top of the joists and the flanges of the channels at the highest point being level with the under surface of the roof slab. In the construction of the roof, the channels were first wrapped in expanded metal lathing bent to the curve of the arch and hooked over the flanges of the channels, which were then enclosed between planks to form centreing, and supported by struts on each side of the columns. The flat roof centring was formed of planks placed parallel to the arch centring planks and supported on battens fixed to them. Sheets of expanded metal were laid on this centring, the long diagonals of the meshes being at right angles to the line of the arches, over the centre of which the sheets were lapped. The concrete was rammed through the meshes, filling up the spaces above the channel bars, the whole floor being brought up to its full thickness in a continuous operation.

To insure the stability of the roof in the direction of the thrust of the arches, the end bays of the reservoir were roofed with heavy concrete work carried on $9\frac{1}{2}$ in. by $4\frac{1}{2}$ in. joists attached to the column stanchions by angle brackets, and supported by the columns at one end and by the end walls at the other. This portion of the roof is reinforced by expanded metal near the upper and lower surfaces, and the concrete is 12 in. thick. The wall ends of the roof joists are bolted to the top of the wall stanchions to give further security.

All the stanchions of the side walls and alternate stanchions of the end walls are anchored to the roof concrete by strips of $1\frac{1}{2}$ in. by $\frac{3}{8}$ in. steel, bent round the top of the stanchion and penetrating the concrete in a horizontal direction for a distance of 2 ft. 6 in. on each side.

By adopting the method of construction described above, the designer has provided ample resistance to all possible stresses, and one feature specially worthy of note is that all parts of the construction afford mutual help to each other. In fact, the reservoir may be likened to a huge tank with a fixed top. The steel framework has to perform duties similar to those performed by the angle frame of a steel tank and the concrete-steel panels between the uprights correspond to the side plates.

Another interesting example of concrete-steel construction in Antwerp is afforded by the dome of the Central Railway Station.

The dome springs from the roof level of the station at a height of 130 ft. above ground level and rises another 130 ft. to the spire by which it is surmounted. This detail of the building was originally intended to be of stone, but as the soil was not sufficiently stable to carry the weight involved, concrete-steel construction was substituted, and further

reduction of weight has been secured by building the dome with hollow walls.

As shown in Figs. 4 and 5, the dome comprises four large arched windows placed upon the sides of a square, and upon these rests the dome proper, which in turn supports a campanile. Each window is in the form of a gallery, with seven arcades surmounted by a semi-circular arch of 32·8 ft. radius. The arches are framed by an archivault 11·5 ft. high, receiving at its periphery the haunches of the dome.

The entire structure, which weighs 1,800 tons, rests entirely upon the columns at the angles of the windows, these being the only points where solid support could be obtained. The columns are Y-shaped in cross section, and at the height of the centres of the arches they are subdivided into three separate members.

The tail of the Y is extended in the diagonal plane in the form of a thrust block rising obliquely between the two shells of the dome. Each limb of the Y forms the abutment of the members

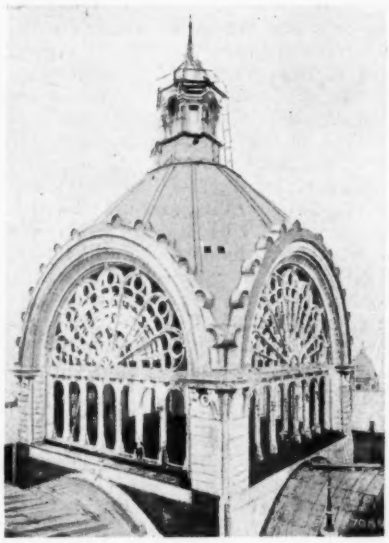


FIG. 5.—CONCRETE STEEL DOME COMPLETED: ANTWERP CENTRAL RAILWAY STATION.

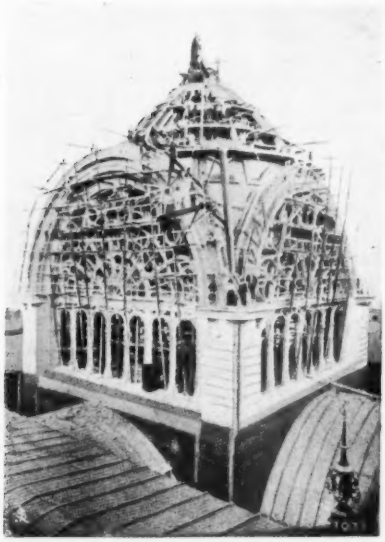


FIG. 4.—CONCRETE STEEL DOME UNDER CONSTRUCTION: ANTWERP CENTRAL RAILWAY STATION.

in the arch, 8·2 ft. high, situated in the archivault. In the horizontal plane passing through the tops of the archivaults, is a member in the form of a flat ring, 4·92 ft. wide, which is supported at eight equidistant points by the tops of the archivaults and the ends of the thrust blocks. This member serves two purposes, balancing horizontal reactions due to the obliquity of the thrust blocks, and resisting tensile stresses due to the ribs of the dome. Tie-rods, commencing at the archivault, go down in the mid-ribs of the arches and extend into the two central columns of each gallery of arcades for the support of a horizontal beam hidden in the entablature of the gallery by which the upper lights are carried.

The dome consists of two superposed shells, separated by a distance varying from 3·28 ft. to 6·56 ft. The internal shell which forms the ceiling of the entrance hall is decorated with sunk moulded panels, which leave only flat bands on the inside of the shell. Some

of these bands are formed by a skeleton of joists and trimmers, which are supported on the annular ring of the dome, and they carry the entire weight of that structure. This skeleton was erected first and served to support the moulds for the panels, which were next filled in with concrete.

The external shell has a uniform thickness of 3·15 in., and is relieved by six moulded ribs following meridian lines. It is supported upon the internal shell by small distance pieces, normal to the two surfaces; this method of support allowing for the unequal expansion of the shell, due to the oblique direction in which it is struck by the rays of the sun.

The construction of the window details was especially difficult because of the great richness of the ornamentation, and of the exactitude with which the moulds had to be made to insure the perfect fit of the different mouldings. Those parts of the windows which form galleries were filled with concrete at one operation in moulds built up in position on the site. For the arched portion of each window, a complete mould was set out on a perfectly level platform, and the mould showed in hollow one face of the entire semicircle.

The concrete was moulded to a thickness of 2 in., and then the moulded part was divided into specially marked portions. Then the moulding, followed by the same division into parts, was repeated to obtain the opposite face. In this way two corresponding portions, placed back to back, formed a hollow structure, representing one element of the window. The parts were afterwards used in building up the framework, just as stones are employed, but steel bars were placed as reinforcement in the hollow space, which was then filled up with concrete so as to connect the two moulded parts and to form a monolithic structure.

This railway station, which has only been completed within the last few weeks, is a magnificent pile of buildings, worthy in every way of the position it occupies among the fine new boulevards of Antwerp, and presenting one more evidence of the great progress made during recent years by the commercial capital of Belgium.

Six-Arch Concrete Bridge at Kinlaven, River Tay.

THE bridge forming the subject of the accompanying illustration affords communication between the Blairgowrie and Coupar Angus districts on the east and the country lying between Glen Almond and Dunkeld on the west, and the advantage may be gauged from the fact that the nearest public bridge below is at Perth, ten miles distant, while that above is at Caputh, 4½ miles distant.

Prior to the construction of the bridge communication had hitherto been maintained by means of a ferry, consisting of two pontoons or barges set parallel to one another and each centered amidships on, and together supporting a platform for carrying the vehicles and passengers for transport.

The whole arrangement travelled on a fixed chain, led across the river and round a pulley carried on the platform, and by means of gearing the pontoons could be set at the desired angle to the current, and the water acting on the oblique surfaces of the pontoons propelled the ferry from side to side.

The bridge is the outcome of the private enterprise of Colonel Richardson, of Ballathie, which adjoins Meikleour, the property of the Marquis of Lansdowne, upon which the bridge is situated. About one half of the cost has been raised by private and public subscription, while the County Council have found the remaining half.

The site of the bridge is about half-a-mile above the crossing of the main line of the Caledonian Railway. The scenery is highly picturesque, and at the spot particularly so, and being within view of Meikleour House it was stipulated that the design should accord so far as possible with the surroundings, and it is generally admitted that in this respect the design and character of the structure is eminently successful.

KINLAVEN BRIDGE OVER THE RIVER TAY. VIEW FROM THE KINLAVEN SIDE OF RIVER BELOW OLD FERRY HOUSE.

The structure is built entirely of concrete, faced, with the exception of the arch rings and impost courses, with red freestone from a local quarry, so that the bridge is to all appearance of stone.

The facing of the piers, spandrel, and wingwalls is of random rubble, while the parapet is of coursed rough-faced ashlar. The arches, which are six in number and of 61 ft. 6 in. span with a rise of 13 ft. 6 in. above the springing, are of two ellipses intersecting obliquely at the crown so as to give a slightly Gothic profile, and with a vertical rise of one foot above the impost course. The arch ring is of 3 to 1 concrete, tapered from 2 ft. in thickness at the springing to 18 in. at the crown, the outer faces being of moulded voussoirs, upon the upper part of which is worked a heavy semi-circular projection. The ring is reinforced by a haunching of 8 to 1 concrete.

Above the arches a corbelling of five courses is carried throughout the length of the bridge, with a total projection of one foot on each side. This corbelling serves to carry the parapet, and while it effects economy in the width of arches and piers to an extent corresponding with its projection, it also affords a feature to break the plainness of the elevation.

The total width of the bridge between parapets is 16 ft. From each side the profile rises on gradients of 1 in 30, which are joined towards the centre by a vertical curve of 2,500 ft. radius.

The impost courses are of concrete, 12 in. deep, with a semi-circular projection.

The piers, which are pointed to form cutwaters, are 5 ft. 6 in. thick at the top, which thickness is carried down for a certain depth, thereafter battering at 1 in 24 until a width of 6 ft. is reached at level of summer water. The foundations, which are in compact gravel, are of concrete enclosed in a close sheeting of American elm, 9 in. thick, which was driven to a depth of 10 ft. below the river bed.

A special feature of the bridge is the fact of advantage being taken of the material at hand for use in construction. The gravel from the river-bed at the site was used for concrete, while the stone was brought from the nearest available quarry some two miles distant. The only imported materials were the cement and timber sheeting for foundations. On account of this the cost of the bridge, exclusive of approaches, amounted to only about £6,100, which compares very favourably with that of a steel bridge, while it affords a much more pleasing and durable structure.

The construction was carried out by means of a steam travelling crane, carried upon a temporary bridge immediately below the site of the permanent structure.

The bridge was designed and carried out by Messrs. Formans & McCall, C.E., 160, Hope Street, Glasgow, and the contractors were Messrs. Jas. Young, Limited, Glasgow.

Direct-Driven Air Compressors with Mechanically Controlled Poppet Valves.

POWER-DRIVEN air compressors are usually provided with either belting or gearing for the transmission of power to the compressor shaft. However, belting requires a great deal of floor space and is a source of constant expense, both on account of lost power and the cost of maintenance. Gearing is more compact and more sightly than belting, but may be noisy and even more subject to wear and friction.

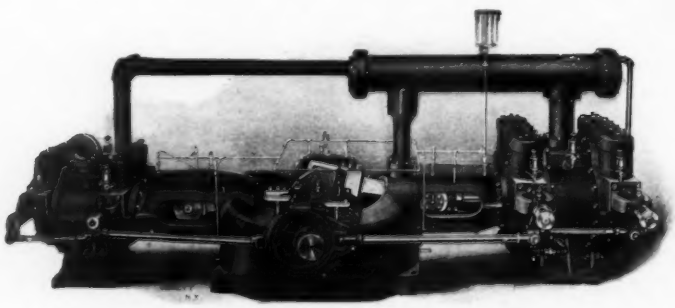


FIG. 1.—DOUBLE-ENDED TWO-STAGE COMPRESSOR FOR DIRECT-DRIVING BY GAS ENGINE.

The two machines illustrated herewith and recently built by the Laidlaw-Dunn-Gordon Co. of Cincinnati, have been specially designed for being driven direct. The first (Fig. 1), is a double-end, two-stage compressor built for direct connection to a gas engine operating at one hundred and seventy revolutions per minute. The cylinders of this machine are 21 and 12 ins. in diameter with a 12 in. stroke, giving a displacement of 810 cu. ft. per minute against 100 lbs. air pressure. The prime mover is to be a 150 h.-p. Crossley gas-engine. The type of frame used in this compressor was selected to harmonise with the Crossley gas-engine design, and to render the entire outfit more compact than if the ordinary duplex arrangement had been used. The crank shaft of the compressor is extended on one side and coupled to the gas-engine shaft, a heavy fly-wheel being placed between the main bearings of the gas-engine and the compressor. The cranks of the compressor are arranged at an angle of 90 degrees with each other, in order to equalise the torque.

Another compressor, built for the General Electric Co., is to be driven by a 150 h.-p. motor, the armature of which is mounted directly on the compressor shaft. The air cylinders of this machine are 18 and 11 ins. in diameter respectively, with a common stroke of 24 ins., the entire outfit operating at a speed of 120 revolutions per minute, and giving a displacement of about 850 cu. ft. per minute against 100 lbs. air pressure. The frame construction is of the Laidlaw-Dunn-Gordon standard rolling-mill type, the motor being placed directly between the frames.

These machines are fitted with the Cincinnati valve-gear, the essential feature of which is the mechanical closing of the discharge, as well as the mechanical control of both the opening and the closing of the suction, this feature enabling these machines to be run at the relatively high speeds involved by direct connection to engine or motor without sacrifice of efficiency. The details of the arrangement are shown in Fig. 2.

As may be seen, each end of the cylinder has two valves, acting in combination. The one nearest the cylinder is a rotary valve, actuated directly by an eccentric rod attached to the valve arm. Above the rotary valve is a spring-closed poppet valve, which closes the passage leading to the discharge pipe. The poppet and the rotary valve act in conjunction to regulate the beginning and end of the discharge; the rotary valve alone opens and closes the suction. The combination of valves has

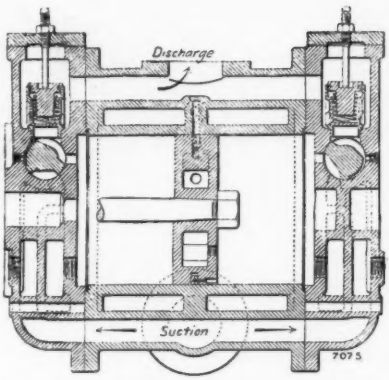


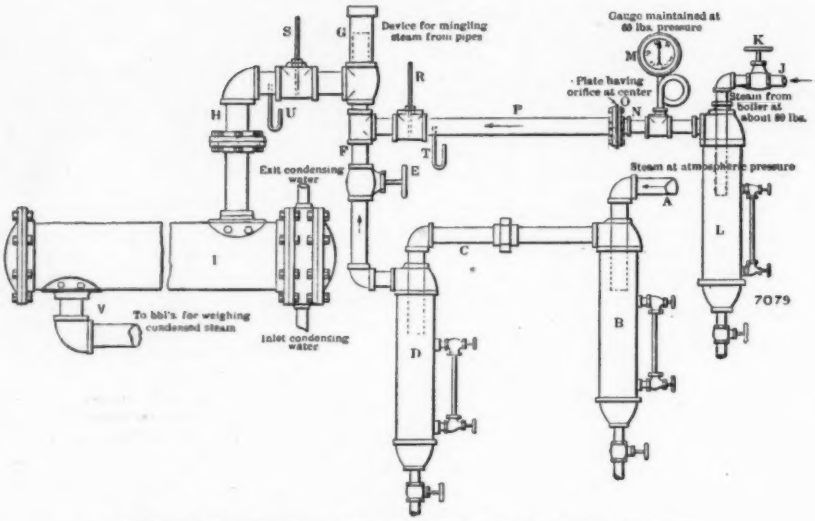
FIG. 2.—LONGITUDINAL SECTION THROUGH COMPRESSOR CYLINDER, SHOWING COMBINATION OF ROTARY AND POPPET-VALVES, CINCINATTI VALVE GEAR.

the effect of giving a variable discharge opening, with fixed time of discharge closing and fixed time of suction opening and closing.

A Method of Determining the Moisture Existing in Steam at Atmospheric Pressure.

PROFESSOR JACOBUS, in the *Stevens Institute Indicator*, describes a method of determining the dryness of steam which consists in mingling a known weight of superheated steam at a given temperature with a known weight of the saturated steam at atmospheric pressure. The steam after being mingled was still superheated and its temperature was measured. Careful measurements were made to determine the radiation of the apparatus. From data thus obtained, the amount of moisture in the saturated steam was determined. The particular problem to be investigated was, how much moisture would be contained in steam at atmospheric pressure after it had passed through two separators of a certain form when placed in series. The general arrangement of the apparatus is shown in the accompanying figure.

Steam generated at very nearly atmospheric pressure flowed through the pipe *A* and entered the separator *B*. From the separator *B* the steam flowed through the pipe *C* into the separator *D*. As has already been explained, the apparatus was designed to determine how much moisture there was in the steam after leaving the


Device for mingling steam from pipes
Gauge maintained at 60 lbs. pressure
Plate having orifice at center
Steam from boiler at about 80 lbs.
Exit condensing water
Steam at atmospheric pressure
To bbl's for weighing condensed steam
Inlet condensing water
7079

APPARATUS FOR DETERMINING MOISTURE IN STEAM AT ATMOSPHERIC PRESSURE.

separator *D*. The saturated steam from the separator *D* passed vertically through the valve *E* and the pipe *F* into the mixing device *G*, and finally through the pipe *H* into the surface condenser *I*. The superheated steam was supplied through the pipe *P*. This steam entered the apparatus in a saturated state and at a pressure of about 80 lbs. per square inch at *J*, and was throttled by means of the valve *K*, so that after passing through the separator *L* its pressure was 60 lbs. as measured by the gauge *M*. The steam in the pipe *N* which was at 60 lbs. pressure, passed through an orifice in the plate *O*, which reduced it to about atmospheric pressure in the pipe *P*. After passing through the orifice at *O* the steam was superheated through the throttling action.

The amount of superheating in the steam passing through the pipe *P* was measured by means of the thermometer *R*. The superheated steam which passed through the pipe *P* was mingled with the moist steam passing upward through the pipe *F* by means of the device *G*, and both the superheated steam passing through the pipe *P* and the moist steam passing through the pipe *F* passes through the pipe *H* into the condensor *I*.

The steam after being mingled in the device *G* was still superheated, but at a less extent than the superheated steam that flowed through the pipe *P*. The temperature of the superheated steam leaving the mixing device *G* was measured by means of the thermometer *S*. *T* and *U* represent two mercury manometers which were used in order to show that the steam in the pipes *P* and *H* was at about atmospheric pressure, the apparatus being arranged with this end in view in order to avoid difficulty in interpreting the results.

The condensed steam from the condenser *I* flowed into the pipe *V*, which led to a barrel where it was collected and weighed. To obtain the weight of superheated steam flowing through the pipe *P*, the valve *E* was closed, and the amount of steam which flowed through the orifice at *O* with 60 lbs. pressure, as registered by the gauge *M* was determined by weighing the condensed steam condensed in the condenser *I*. After determining the rate of flow of steam through the orifice *O* with 60lbs. pressure, the valve *E* was opened, and the steam generated by the boiler was allowed to flow into the mixing device *G* along with the superheated steam flowing through the pipe *P*. The amount of superheated steam flowing through the pipe *P*, under the latter set of conditions, would be the same as with the valve *E* closed, because the rate of flow through the orifices *O* would not be affected for a given steam pressure in the pipe *N* by altering the pressure in the pipe *P* on the

exit side of the orifice even through a considerable range; and as there was practically no variation in pressure shown by the manometer T with the valve E open and closed, the weight of steam flowing through the orifice at O was constant.

The weight of steam condensed in the condenser I was determined with the valve E open, and with the saturated steam at atmospheric pressure mingling with the superheated steam. The weight of steam thus determined was the sum of the weights of the saturated and the superheated steam; and as the weight of superheated steam was known, that of the saturated steam could be determined by deducting it from the total amount found by weighing the discharge from the condenser I.

With the exception of the condenser I, the apparatus was thoroughly coated with hair felt in order to diminish the radiation. In order to determine the amount of heat lost by radiation for that portion of the apparatus which affected the computations, the difference in the readings of the thermometers R and S with the valve E closed was determined with the superheated steam flowing through the pipe P, at the rate which was adopted in the tests. To fix the rate that was adopted in the tests, the steam in the pipe N was maintained at 60 pounds pressure.

In obtaining the radiation readings, and also in the regular tests, the apparatus was run for an hour or more in order to thoroughly heat it.

The thermometers R and S were placed through corks inserted in the pipes and the steam acted directly on their bulbs.

The method of computing the moisture, together with the results for the average data obtained in the experiments, is as follows:

Let W = weight of steam and any contained moisture flowing from the separator D through the pipe F in pounds per hour;
w = weight of steam flowing through the orifice O in pounds per hour;
T = reading of the thermometer S with saturated steam at atmospheric pressure in the pipes F and H;
T_1 = reading of the thermometer S with superheated steam at atmospheric pressure in the pipes P and H, and at the time of measuring the quality of the saturated steam;
T_2 = reading of the thermometer R with saturated steam at atmospheric pressure in the pipe P;
T_3 = reading of the thermometer R with superheated steam at atmospheric pressure in the pipe P, and at the time of measuring the quality of the saturated steam;
R = number of degrees of radiation;
P = percentage of priming in the saturated steam leaving the separator D.

Then we have

$$P = \frac{(T_3 - T_2 - R)\,w - (T_1 - T)\,(W + w)}{20{\cdot}1\,W}.$$

In our tests the following average data was obtained:

$W = 252{\cdot}4$ $w = 242{\cdot}8$ $T = 212{\cdot}0$ $T_1 = 2{\cdot}386.$
$T_2 = 210{\cdot}0$ $T_3 = 266{\cdot}4$ $R = 1{\cdot}3.$

From the above data we obtain $P = 0{\cdot}04$ per cent., or the amount of moisture in the steam after passing through the two separators was less than one-tenth of one per cent.

TURBINE MOTOR-DRIVEN SINKING PUMP.

This small amount was within the probable error of the observations, and the tests therefore indicated that the steam was dry after passing through the separators.

A New Turbine Motor-Driven Sinking Pump.

MESSRS. MATHER AND PLATT, LIMITED, have recently constructed an entirely new form of sinking pump, the striking features

of which are the limited dimensions and weight for the output which the pump is capable of giving. A recent test of one of these pumps showed a capacity of 500 gallons of water per minute, with a maximum head of 300 feet.

The accompanying illustrations explain the construction.

Just below the four-way delivery pipe at the top is a four-pole totally enclosed motor, wound for 500 volts at a speed of 1,150 revolutions per minute, and having an output of 110 horse-power, this being a large margin of power for contingencies beyond what is actually required for the specified output. The armature runs in vertical bearings, and is connected by a flexible coupling to the pump. A ball-bearing at the top of the motor case takes the weight of the armature and spindle, and a similar bearing just above the pump takes the weight of the impellers and spindle.

Special arrangements are provided to allow of the pump going "on blast," *i.e.*, of continuing to run while lifted clear of the water.

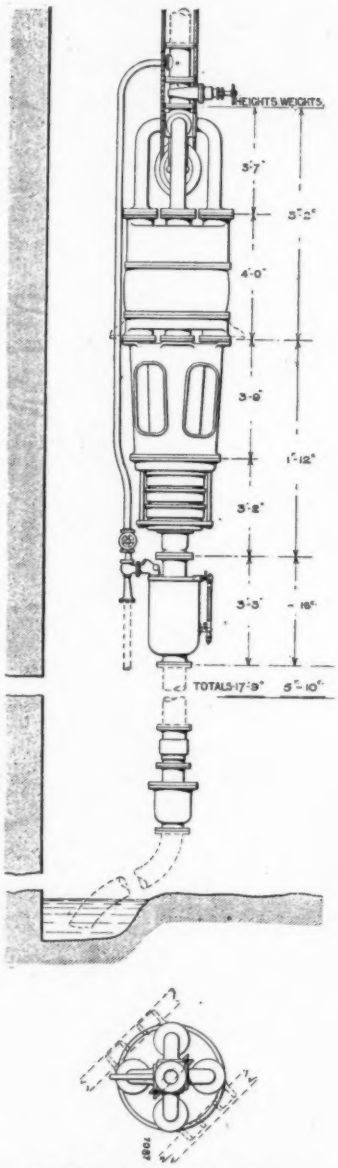
A distance piece between the pump and the motor forms a four-fold passage for the discharge of water from the pump. This four-way pipe is carried up between the motor poles, thereby saving space, protecting the pipes and keeping cool the motor.

The four-fold pipe is carried up through the motor casing terminating in one junction pipe at the top, attached to which is a sheave to take a wire rope for raising or lowering the pump in the shaft.

The overall dimensions of the pump are 17 ft. 9 in., the greatest diameter, 3 ft. 5 in., and the total weight, 15·5 tons.

Messrs. Mather and Platt, Limited, are at present manufacturing several pumps of this type, two sets being for the Dutch East Indies and one for the north-east coast.

This construction of pump marks a great step in advance of other types of sinking pumps, hitherto employed both on account of its reliability, compactness, convenience, and economy, and there is every prospect of a wide field and successful future for their application to mining purposes.



TURBINE MOTOR-DRIVEN SINKING PUMP.

Some Large Morgan Blowing Engines.

By the courtesy of the Morgan Engineering Company of Alliance, Ohio, we are enabled to give some particulars and illustrations of four large blowing engines, recently

designed and built by them for the Rochester and Pittsburg Coal and Iron Company at Du Bois, Pa., and the South Chicago Furnace Company, South Chicago, Ill.

The engines are of the vertical long crosshead type, simple, non-condensing and have the steam cylinders below the crosshead and the air cylinders above. The diameter of the steam cylinders of all these engines is 44 ins. while the air cylinders are 84 ins. diameter. The stroke of the engine is 60 ins. Thus at 42 revolutions per minute each machine will deliver about 16,000 cu. ft. of free air per minute, at 25 lbs. above atmospheric pressure. These engines were constructed under the most rigid specifications as to workmanship and material, and at the present time are giving the best of satisfaction.

The main bed-plate rests directly upon the foundation and is cast in one piece from the best quality of iron. This bed-plate is of very massive form, strongly ribbed and in every way suitable for rigidly supporting a heavy machine like these engines. The bed-plate is cored to receive a thick layer of babbitt metal which forms the bearings of the fly-wheel shaft. These bearings are very carefully bored to size, scraped and provided with ample means for lubrication. The caps for the main bearings are strongly made and held in place by four 3 in. tap bolts.

The fly-wheels, of which there are two to each engine, are 20 ft. in diameter, each weighing about 50,000 lbs. They are well counter-balanced and calculated to run at a speed much in excess of that to which they are subject under the hardest service. The central hub of each fly-wheel is of cast iron and strongly keyed to its shaft. These hubs form crank discs into which the crank pins are forced and riveted. The rim of the wheel is made in halves and securely fitted to the discs. In the rim it will be noticed there are recesses to allow for barring the wheel.

The crank pins, which are 10 ins. in diameter, are made of the very best grade of steel forgings of about ·40 per cent. carbon, and as stated above, are forced into crank discs and riveted thereto.

The main shaft is 20 ins. diameter. It is also of the best quality of forged steel and is ground true on dead centres.

The connecting rods, of which there are two to each engine, are of open hearth forged steel, ·25 to ·30 per cent. carbon.

FIG. 1.—MORGAN BLOWING ENGINE.

These rods are of the solid end type, provided with the necessary brass boxes, babbitt lining, adjusting wedge, &c., arranged to take any wear in the bearing.

The steam cylinders are made of specially selected cast-iron stock, and each contain four valve chambers for the valves which are of the Corliss type. The exhaust chamber is cast separate from cylinders, thus reducing internal condensation. The

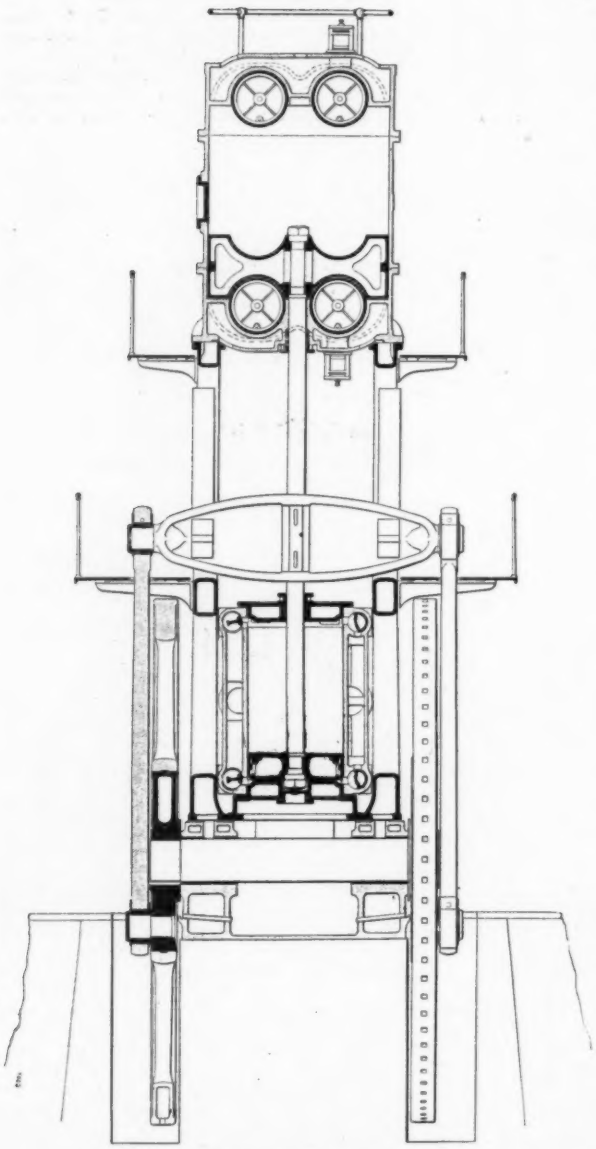


FIG. 2.—VERTICAL SECTION THROUGH BLOWING ENGINE.

steam cylinders are lagged with non-conducting covering and furnished with sheet steel jacket with corner angles. A relief valve is located in each end of each cylinder.

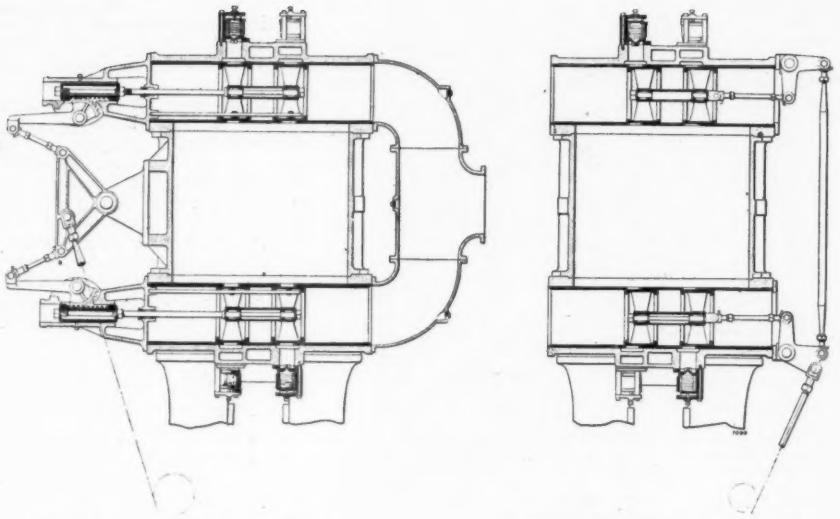
The crosshead is a steel casting carefully annealed and ends turned to form the crosshead pins. The shoes of the crosshead are of cast-iron, faced with babbitt metal.

Each engine has two side housings or frames, which, as will be noted from the illustration, extend up and form the support for the air cylinder. These housings are rigidly constructed and stiffened by cast-iron cross braces.

As is the case with the steam cylinder, the air cylinders are also composed of specially selected cast-iron stock, having as close a grain as consistent with good machining.

The air valves are of patent horizontal piston type, both inlet and outlet valves being double ported and 24 inches in diameter. The inlet valve has a simple harmonic action, but the outlet valve mechanism is so arranged as to give quick opening at the instant of delivery and insure a long pause on return stroke. The whole system receives its motion from the lay shaft, gearing from the main shaft of the engine. Great care was used in designing these valves and connections that they might be sufficiently strong, and yet not contain weight detrimental to their proper operation.

As stated, the steam cylinders are fitted with



SECTION THROUGH AIR-DISCHARGE VALVES. SECTION THROUGH AIR-INLET VALVES.

FIG. 8.

standard Corliss type valve gearing, operated through single eccentric and wrist plate. The governor is of the ball type driven positively by gearing, with speeding device to govern the engine through a considerable range without stopping it.

The total weight of each of the engines described is about 400,000 pounds.

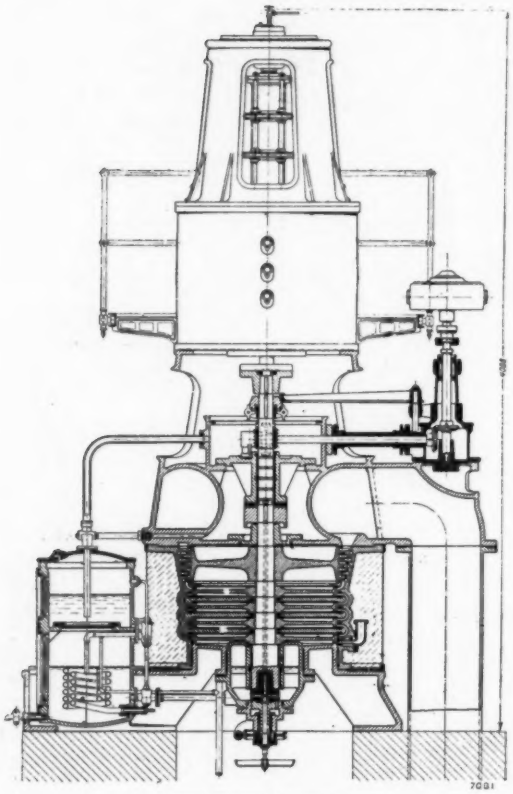
A New German Steam Turbine.

In a lecture recently delivered before the Association of German Engineers, Mr. Wengler described a steam turbine now being introduced by the Union Limited Co. of Essen.

This turbine, when constructed in small sizes, is an action turbine having one or several pressure stages and multiple speed staging in the various pressure stages, while in large sizes it embodies a combination of a multiple-step action turbine at the high pressure end, with a multiple-step reaction turbine at the low pressure end. The low number of stages and the use of speed staging in connection with small wheel diameters and speeds of 3,000 to 4,000 revolutions per minute are special features of the turbine. Stuffing boxes have been done away with in the small engines. In front of each pressure stage conical nozzles have been used in small sized turbines because of the large heat gradient, and the same applies to the first stage in large sized engines. The nozzles have been combined by groups arranged opposite one another, so as to avoid any lateral thrust.

The vanes in the action wheel are similar to those of Pelton wheels, being provided with U-shaped pockets reversing the steam jet and thus insuring the best relative hydraulic efficiency. In order to diminish friction in the steam, the discs have been polished and the frictional resistance on the walls of the vanes reduced as far as possible by careful grinding.

The regulation of the turbines is effected by calculating the amount of steam supplied according to the actual load, while the pressure in front of the nozzles is maintained constant, and the tension, at least in the first stages, is altered little. The hydraulic and thermo-dynamic efficiency is thus altered only to a small extent within wide limits of load variation, that is to say, the steam consumption is hardly influenced by fluctuations of the load. The number of working nozzles is adapted to the actual load by a slide valve, actuated



NEW GERMAN TURBINE.

from the governor. Independent safety governors have also been provided.

The number of stages required by the turbine is small, involving a greater reduction in the length and floor space as compared with pure reaction turbines. The various compartments are tightened at the high pressure end by means of partition walls and packings on the shaft. The steam expands in the first stage to two to three atmospheres, and the exceptionally high speed of the steam in the first stage is fully utilised by speed staging. Funnel-shaped paddles have been arranged to receive the steam jet, to avoid any vortices and to lead the jet to the guiding vanes fitted into the partition walls, playing the part of nozzles before each stage and generating velocity. The guiding vanes occupy an ever-increasing portion of the circumference from one stage to another until in the last action stage they are closed completely.

An automatical continuous oil circulation has been provided, dispensing with any pumps. Owing to the pressure difference between the high pressure and condenser sides, the lubricating oil is conveyed through a hole in the shaft from the lower step bearing to the upper step bearing, this oil circulation being regulated automatically according to the oscillations in load of the engine.

The Danger of Lightning in Armoured Concrete Constructions.

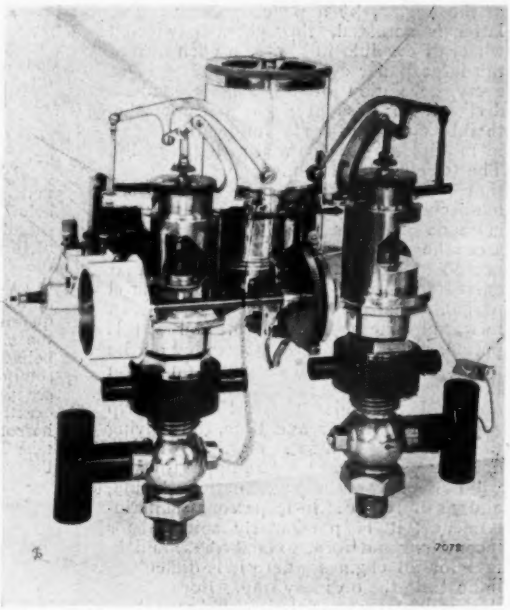
It is a well-known fact that any constructions made entirely of iron are practically immune against the effects of lightning, as the amount of electricity accumulated in the case of a lightning stroke is allowed to distribute itself over the large surface of the roof and to flow off to the earth at many places with greatly reduced intensity. Conditions are quite similar in connection with buildings made entirely of armoured concrete, as the discharging current will find the roofing iron and distribution rods of an armoured concrete roof, struck by lightning, a good conductor of electricity, so as to flow off to the more substantial girder iron to which the roofing iron is connected by wire meshes. Therefore, says *Beton und Eisen*, neither artificial lightning arresters nor parts of such will be required in connection with any construction consisting entirely of armoured concrete.

A Continuous Double Diagram Indicator.

The accurate determination of the power developed by a steam engine has hitherto involved the use of two ordinary engine indicators, one being applied at each end of the cylinder, in order that both diagrams may be obtained during the same stroke. The method, however, involves difficulties, and necessitates, amongst other things, at

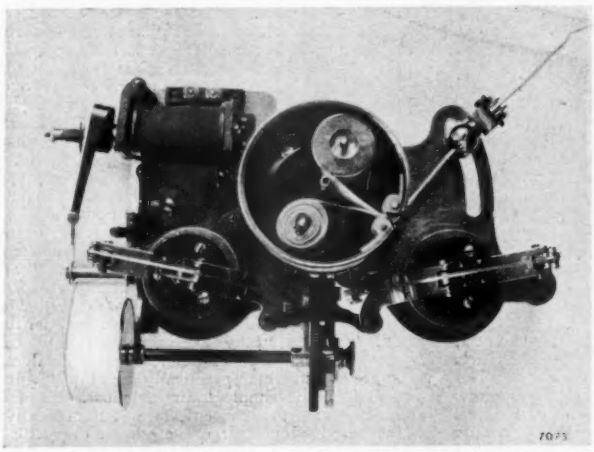
least two locked indicators. It is hardly necessary to point out that the use of a single indicator by which a diagram is taken from one end of the cylinder only leads to inaccuracy in the calculation of the power developed, as both load and speed may vary between two successive cards.

An instrument has, however, been recently devised which not only takes pressure diagrams simultaneously and automatically from both ends of the cylinder, but also records the time and number of revolutions, thus providing all the elements required for a correct indication of the engine during the same stroke. The instrument, the general appearance of which may be gathered from the accompanying illustrations, is known as the Cipollina Continuous Double Diagram Indicator with McInnes-Dobbie Patent External Spring Cylinder Arrangement. It consists of two indicator cylinders with pistons and parallel motions, and having the pressure springs arranged exterior to the steam cylinder which renders the indicator particularly accurate at high pressures.



"CIPOLLINA" CONTINUOUS DOUBLE-DIAGRAM INDICATOR (FIG. 1).

The indicator is not intended to take diagrams at every revolution, the intervals at which they can be taken being regulated by an interval wheel to give diagrams at every twenty-five, fifty or one hundred revolutions. The paper drum reciprocates, and the pencil arms rise and fall, however, at every stroke, and at the arranged moment of contact determined by the interval wheel, one pencil gives a diagram from the top end of the cylinder and the other pencil one from the opposite end, both being taken simultaneously and on the same length of paper. Immediately the diagrams are taken, the pencil points are released, and a fresh length of paper is drawn on to the drum, that portion being occupied by the diagrams being wound into the interior of the paper cylinder as shown in Fig. 2. On a second paper drum, seen on the extreme left of Fig. 1, are recorded the revolutions



"CIPOLLINA" CONTINUOUS DOUBLE-DIAGRAM INDICATOR (FIG. 2).

of the engine, by a pencil pointer. The latter is actuated, through a pawl and wheel discernible in Fig. 1, at each turn of the large paper cylinder, and therefore at every revolution of the engine, and is designed to miss at every tenth stroke, thereby enabling the revolutions to be read in multiples of ten as well as individually. The electrical attachment by which the time is registered is seen on the top left-hand corner of Fig. 2. Electrical contact is made with the two connections there seen, the other end of the wire being connected to a clock suitably arranged so that current can pass through at any desired period. The pencil point is then drawn forward by the armature of the coil for this period, so that the time is recorded on the paper strip. The roll of paper on which the power diagrams are traced can then be arranged in conjunction with the strip showing revolutions and time, thus giving the essential elements required for an accurate engine trial. The apparatus, as will be seen, is entirely automatic in action, and as it requires little personal superintendence, it is particularly suitable for locomotive and torpedo boat work, and in fact for all engines where it is difficult to indicate in the ordinary way. For exhaustive and accurate trials it would appear to be indispensable. It has been patented throughout the world by the makers, Messrs. Dobbie McInnes, Limited, 45, Bothwell Street, Glasgow, to whom we are indebted for the foregoing particulars and photographs.

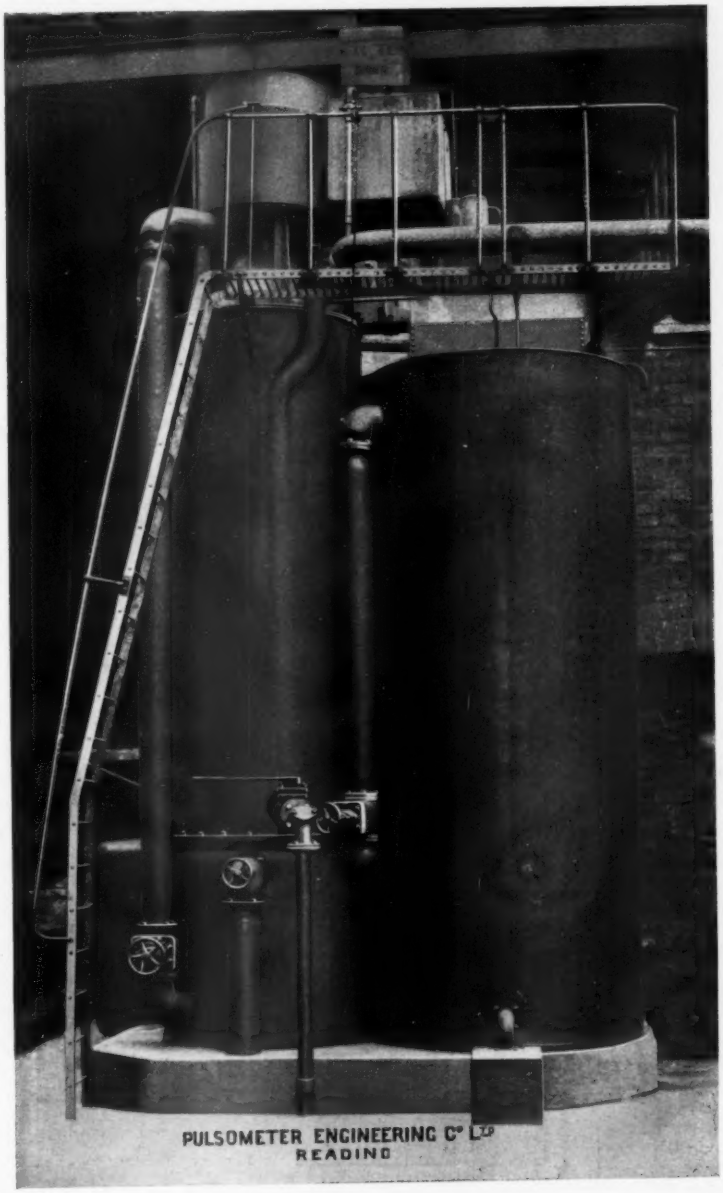
The "Criton" Water Softening Plant.

We illustrate herewith a water softening and heating plant recently built by the Pulsometer Engineering Co., Limited, of Reading, for softening the boiler feed at a London firm of manufacturers. The apparatus is constructed to treat and heat 2,000 gallons of water per hour. East London water is used, and notwithstanding the well-known scale forming characteristics of this water, the deposit in the boilers during the first ten weeks, we are informed, did not exceed the thickness of a sheet of note paper, and on opening the boilers after a further run of sixteen weeks it was found that the scale had not appreciably increased. The hardness of the water had been reduced on an average to three degrees (Clarke's Soap Test), since the plant has been at work.

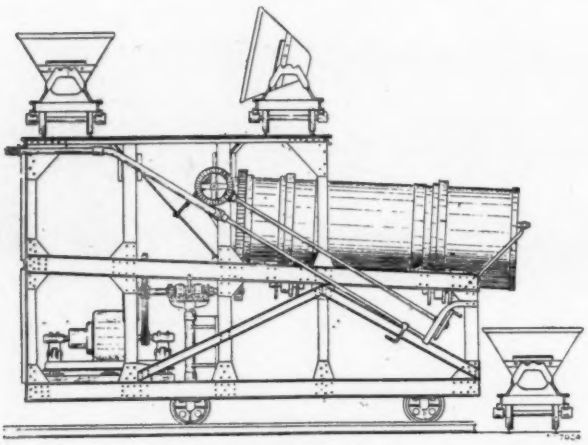
A description of the principle on which this plant works will be of interest to our readers. The hard water is admitted to a syphon tank containing a float which is mechanically connected with two displacers. When the water rises in this tank the displacers are drawn out of the tanks containing the lime water and soda solution, which are then automatically filled up to a given level by means of ball cocks. The syphon tank is so arranged that it discharges its contents automatically directly the water reaches a certain level, thus ensuring an exact quantity of water being discharged at each emptying. The ball cocks in the reagent tanks are set to fill the tanks to a point just below the discharging troughs, so that when the displacer enters, say, the lime tank, a bulk of lime water exactly equal to the portion of the displacer submerged is pushed over into the mixer. The displacer is capable of easy adjustment, so that any smaller or larger quantity of lime water can be delivered to suit the chemical nature of the hard water then being dealt with. The displacer in the soda solution is similarly arranged. It will thus be seen that the discharge of the reagents is exactly dependent on the quantity of water to be softened. If this is reduced, the syphon tank fills fewer times per hour, and consequently the number of times the displacers work is reduced in the same proportion.

The discharges from the hard water syphon tank, and from the lime and soda tanks, all meet at the same time and at the same place, viz., the mixer, thus ensuring an immediate and thorough mixture in their proper proportions. From the mixer the treated water is passed through a special exhaust steam heater in the settling tank by means of which the temperature can, if desired, be raised to boiling point. There are several reasons why it is advantageous to heat the water after the reagents have been introduced instead of before, the chief being that the chemical reaction is thereby hastened and rendered more complete, whilst there is less loss of heat before the water enters the boiler. From the heater the water passes to the bottom of the settling tank, whence it steadily flows upwards, leaving in its progress the heaviest of the suspended matters caused by the action of the softening process. From here it passes through the filter, emerging at the filter "outlet" soft and bright. The filter is cleaned without the removal of the filtering medium. The lime tank is recharged with lime daily, and the spent lime drawn off. The total attention required is that of one man for not exceeding an hour once in twelve hours.

In this particular case the plant is lagged to prevent the loss of heat, but the Pulsometer Company have erected several softeners to treat the water cold, and these have also been most successful. We understand that they have recently slightly altered their design in order to still further simplify the apparatus, and are now producing a plant which has no ball valves at all, and in which practically the only moving parts are the simple lever and float. In this later plant the reagents are automatically measured by measuring vessels at every discharge of the syphon tank. The capacities of



"CRITON" WATER-SOFTENING PLANT.



PORTABLE CONCRETE MIXER.

these measuring vessels can be easily and rapidly varied to suit any change in the chemical nature of the water, and by this means the method of regulating the quantity of chemicals is precisely that adopted by the chemist when experimenting in the laboratory, and great accuracy can, therefore, be obtained.

The filter remains the same as in the type of plant already described, being still a special feature of the "Criton" Water Softener, since the bed is cleaned in position merely by opening certain valves, and does not require to be renewed. Probably only those who have had experience of the trouble of getting filter beds washed by hand or emptied out when dirty will realise fully what an immense saving of labour this is.

A Portable Concrete Mixer.

In a recent issue of *Teknisk Ugeblad*, Christiania, a description is given of a novel portable concrete mixer, constructed by a Belgian company. In connection with the accompanying diagrammatic view, the following particulars will be found of interest. Cement, sand, and gravel are filled in the proportions required into tip wagons that are conveyed up a plank flooring installed above the machine. The contents of the wagons are discharged into a triangular hopper, arranged between the rails, from which, through a shoot, the mass is introduced into the mixing drum. The latter is made of steel plates 12 mm. thick, and provided with a toothed rim, to which the motion is transmitted from the motor through a transmission and a four-grooved friction wheel. The drum is, moreover, provided with two cast-steel rings running on four-wheel discs of 260 mm. diameter.

Inside the drum are installed nine angle-iron paddles 850 mm. in length, mixing the mass during rotation, and ensuring its homogeneity. There is, further, in the longitudinal axis of the drum, an iron tube of 60 mm. internal diameter, provided with three rows of holes. The upper end of the tube is connected to water conduits provided with cocks that allow of the required amount of water being accurately adjusted.

The concrete is discharged from the drum immediately into tip wagons, in which it is conveyed to the place of consumption.

The concrete mixer is mounted on a truck, the motion to which is imparted by the electromotor referred to without the use of any friction clutch.

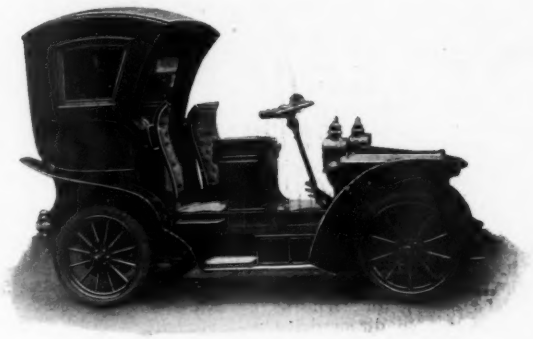
The "Manchester" Motor Wagon.

Messrs. Turner, Atherton & Co., Limited, of Denton, Manchester, have recently taken up the manufacture of motor vehicles for commercial purposes, which is being worked entirely as a separate department from their electrical business. The "Manchester" motor wagon is being made under the patents of Dr. A. W. Brightmore, M.Inst.C.E., whose system has been evolved after long and costly experiments. Arguing

that the correct principles of traction in the case of horse-drawn four-wheeled vehicles have been established beyond question, Dr. Brightmore sought to apply them in his system of motor traction; for example, following the principle that the tractive effort should be applied to the fore part of the carriage, in the vehicle under review the motor drives the front wheels.

Again, to enable the vehicle to accommodate itself to any unevenness of the ground without a strain on the springs, the fore-carriage carrying the machinery is connected to the carrying platform by a ball-and-socket joint, and is kept parallel to the platform by a roller moving in a segmental channel attached to the platform. This method of connection permits the front axle to assume any angle relative to the back axle whether in the horizontal or vertical plane. Another feature is that the steering wheel applies the steering brake on one side or the other of the differential gear; and, further, any deviation of motion when steering is not taking place is prevented by means of a device which interposes between the two parts of the differential shaft a resistance sufficient to overcome any tendency of the road to cause such deflection which ensures the front wheels revolving together.

A lorry built to carry a maximum load of six tons has a platform 16 ft. long by 7 ft. 3 in. wide, consisting of a rolled steel frame of bulb angle section with a 1½ in. pitch pine floor. It should be noted that the overall length of this vehicle is only 18½ ft. which greatly increases its handiness. The boiler is of the water-tube type with short tubes, and is fed by a gear-driven pump, although an injector is fitted for emergencies. The engine is compound, with extra large wearing surfaces, and a variable cut-off and reversing gear. It has cylinders 4½ in. and 7½ in. diameter by 6 in. stroke. The cranks are at right angles, giving a nearly uniform effort on the crank-pin, and thus permitting a fly-wheel to be dispensed with. The normal speed of the engine is 500 revolutions per minute, and it is geared down to give a speed of six miles per hour on the road, whilst this speed can be varied either by the throttle valve or cut-off gear. A slow-speed gear is provided for very steep hills, but the variable cut-off makes its use seldom necessary. The moving surfaces are oiled by splash and forced lubrication.



THE "HERALD" MOTOR-HANSOM.

The exhaust steam passes through the feed-heater on its way to the boiler chimney.

The wheels, 3¼ ft. in diameter, are of the composite type, with metal spokes and hub, and ash felloes having weldless steel tyres 8 in. wide, hydraulically pressed on. The front and back wheels are of the same pattern, and the same remark applies to the springs.

In addition to the reversing action of the engine, exceptionally powerful brakes of the compensated type are fitted.

In a future issue we hope to be able to give full illustrations of this interesting vehicle, together with some particulars of tests recently carried cut.

Motor-Hansoms for London.

THE new motor-hansom designed for London cab traffic by the Herald Manufacturing Co., Limited, Manchester, and which are to be placed in service by the Metropolitan Motor Cab and Carriage Co., Limited, has, we are informed, given complete satisfaction during the probationary period, in which several were plying for actual hire.

The details of construction, method of control and working costs have proved the vehicle to be well adapted for the purpose for which it was introduced, and that the wearing surfaces after 8,500 miles run were in extremely good condition. The vehicle is illustrated in the accompanying

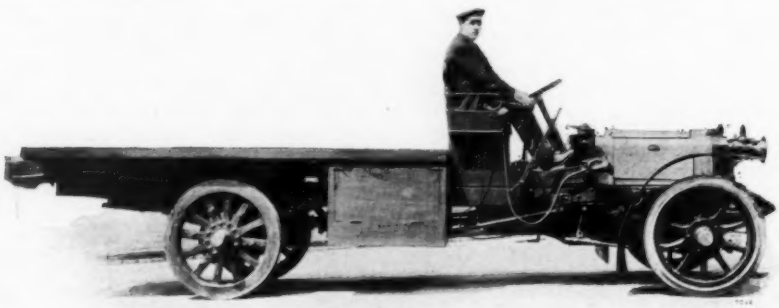
half-tone, from which it will be seen that it is neat in design and comfortable in appearance. The motive power is supplied by a 12 h.-p. two-cylinder engine working at 1,200 revolutions per minute, the method of control in conjunction with the change speed gear permitting a variable speed of from 3 to 25 miles per hour. The radiator and bonnets are of special design providing a large cooling surface and the circulation is obtained by a centrifugal pump driven off the fly wheel. A manometer fixed on the dashboard shows clearly when the water is circulating properly.

The speed gear is controlled by a single side lever giving three speeds forward and one reverse with direct drive on the high speed.

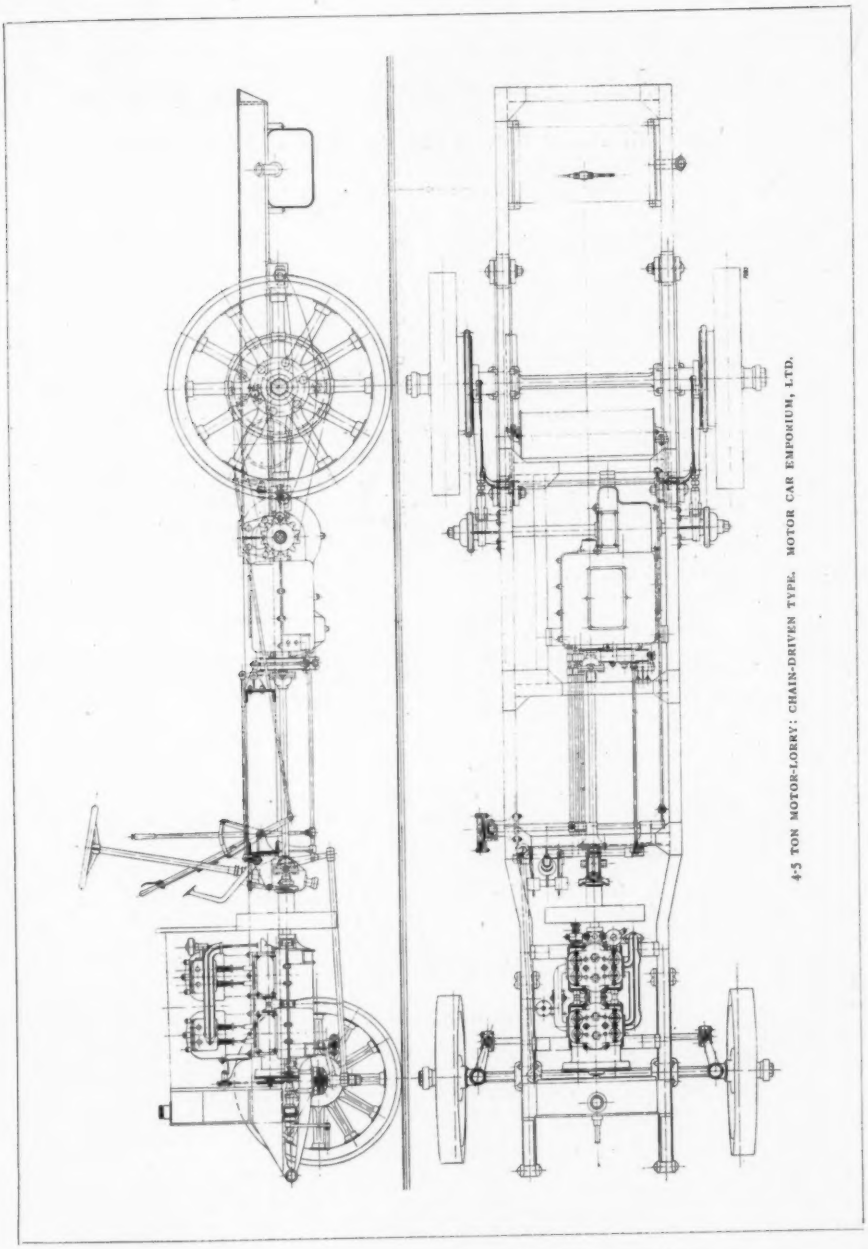
The brakes are of special design arranged to work in either direction, those on the driving wheels, which are actuated by a hand lever at the right of the driver, being formed of steel bands to which cast-iron segments are riveted. The foot pedal operates a band brake on the brake drum fixed to the gear shaft. Chain driving is adopted; Brampton's chains being the type used. The petrol tank which is fitted under the seat has a capacity for 120 miles. The wheels which are of equal size are of artillery pattern and extra long, and flexible laminated carriage springs are fitted to ensure comfortable travelling. Mr. E. R. Calthrop, M.Inst.C.E., estimates the cost of working, exclusive of administration expenses but inclusive of annual depreciation of 20 per cent. on cost, and insurance, will be £365 per vehicle per annum on a minimum total of sixty cabs constructed with interchangeable parts. There is no doubt that in consequence of the prompt acceleration the complete control of steering and slowing down of these vehicles the gain in the mean speed, especially in the more congested streets will be considerable as compared with an ordinary hansom cab. Such a saving in time must appeal to every user, with the result that there is every prospect of their becoming extremely popular.

The Motor Car Emporium's Motor Lorry.

The accompanying illustrations are those of a 4 to 5-ton lorry now being introduced in this country by the Motor Car Emporium, Ltd., after very exhaustive trials carried out in connection with the German army. The vehicle is driven by a 4-cylinder vertical petrol engine developing 26 to 30 h.p. at normal speed of 850 revs. per min. To avoid delays on the road two independent sets of ignition are provided and lubrication is effected by a pump in manner similar to that adopted on automatic lathes, the oil being taken from the bottom of the crank chamber. A radiator which is also a water tank is placed in front of the motor and the cooling of the water is effected by means of the rotary fan. Four speeds are provided actuated by the same lever, and the gears, which are contained in an oil-tight box, are of the best chrome-nickel steel. The transmission from the gear box to the driving wheels is by a Cardan drive modified in such a way that the rear wheels are driven by two separate shafts. The chassis of this vehicle, it may be mentioned, has been utilized for the motor-busses supplied by the company during the last few weeks for the London Road Car Company's service.



4-5 TON MOTOR LORRY: LIVE AXLE TYPE. MOTOR CAR EMPORIUM, LTD.



4-5 TON MOTOR-LORRY: CHAIN-DRIVEN TYPE. MOTOR CAR EMPORIUM, LTD.

The Liège International Exhibition.

(For Preliminary Article see Vol. XII., pp. 831—839.)

Of the 35,500 square yards comprising the Halle des Machines at the Liège Exhibition no less than 22,400 sq. yards are occupied by Belgian exhibits comprising an unusually interesting collection of boilers, locomotive and stationary engines and miscellaneous machinery. Many admirable exhibits are also to be found in the German and French sections, those in the British portion being perhaps the least representative. They certainly do not serve to indicate to the foreign visitor the extent and variety of our national industry, although the individual exhibits are fine examples of workmanship and design. The chief British stands are those of Sir W. G. Armstrong, Whitworth & Co., Alfred Herbert, Reavel & Co., Thos. Robinson & Sons, W. & T. Avery, and the Robins Belt Conveyor Co., and taken altogether they occupy less space than the stands of the Société Anonyme John Cockerill, of Seraing—the leading Belgian establishment—which alone occupies an area of 15,000 sq. yards. The American section is of even less importance than the British, which, however, may be accounted for by the fact that many of the leading engineering establishments of the United States are directly represented on the Continent.

Confining our attention to exhibits of more than passing interest only, mention must first be made of the Société Cockerill enclosure, in which are displayed three of their well-known type of gas engines, a 300 h.-p. compound steam engine direct coupled to a dynamo, a 10,000 h.-p. rolling mill engine, a 50-metre propeller shaft and some examples of marine ordnance. The largest gas engine is a 1,200 h.-p. horizontal four-cycle double-acting tandem type, utilising blast furnace gas. The cylinders have a diameter of 1 metre with a stroke of 1·1 metre, the normal working speed being 100 revolutions per minute. At the close of the exhibition it will be used by Messrs. Cockerill themselves for rolling mill driving.

Another engine designed for working with blast furnace gas is of the vertical double-acting twin-cylinder type operating on the four-cycle principle and developing 150 h.-p. at the normal speed of 280 revolutions per minute. The diameter of the cylinders is ·325 m. and the stroke ·350 m. The other engine is designed for use with coke-oven gas and is of the horizontal four-cycle twin-cylinder double acting type developing 500 h.-p. at 135 revolutions per minute. The cylinder dimensions of this engine are, diameter ·6 m. stroke ·8 m. The cylinders of these engines, which are of cast iron, are water jacketed in the usual way with ample facilities for cleaning purposes. An electrically-driven turning gear provided in the two larger engines is fitted close to the outside bearings and acts on the teeth of the fly-wheel rim. The ignition system is electric and is governed by the cam-shaft. The gas supply is regulated by a centrifugal governor, the compression remaining constant. Compressed air is used for starting the engine, the turning gear above-mentioned being used for placing the engine in starting position. The water cooling system is extended to pistons, piston-rods, stuffing boxes, exhaust valves and exhaust valve chests, the water pressure required being 14·7 lbs. per square inch.

The compound condensing engine is of the Francois double piston type, and develops 300 h.-p. when running at a speed of 140 revolutions per minute. The cylinders are arranged twin fashion and have a stroke of ·750 m., the diameter of the high pressure being ·375 and of the low pressure cylinder 650 m. The steam distribution is by means of piston valves, of which there are two provided for each cylinder; these act alternately for admission and exhaust through a single port. A small auxiliary valve is fitted inside the main piston valve actuating the cut-off. A governor regulates the travel of the small valve. The feature of the engine is the double piston, the object of which is to provide the steam jacket on the inside of the cylinder walls and the surfaces of the piston with steam, the jackets communicating with the open space formed by the two pistons.

(To be continued.)

Locomotive and Railway Notes.

By CHARLES S. LAKE.

British Locomotive Practice in 1905.

THE latest developments in locomotive engineering, although constituting a further material advance towards finality in the matter of overall dimensions, should not be taken as indicating that the maximum of efficiency has been reached, or that the modern ideal of high power, combined with great economy in operation, is conspicuously identified with any one particular design more than another of the same class.

It is not, of course, to be expected that with increasingly strenuous conditions of service, the cost of locomotive operation should be accompanied by results which will compare favourably with those of the past, when totally different, and needless to say much less exacting, circumstances prevailed. Nevertheless, it is a matter of growing importance to every railway company that the cost of construction, maintenance and working of locomotives should be reduced, so far as is consistent with efficiency in the performance of the work required.

But, other circumstances apart, it is imperative that in order to meet existing traffic demands and to provide for those of the near future, the power capacity of the individual locomotive should always be a primary consideration when preparing new designs, whatever consequences the observance of this principle ultimately entails. The result of this is to be seen in the rapid development, which has taken place during the last year or so in the size and weight of locomotives intended for maximum duty on the leading railways.

So far as this country is concerned, the present year will rank as noteworthy, as having provided special evidence to show that the necessity for increasing the working value of locomotives is fully recognised, for within the next few months the whole of the new designs prepared earlier in the year will, it may be anticipated, have been materialised, and the engines placed in service; indeed, this has already been done in a few instances, and these will probably have been supplemented by others by the time these notes are in print.

The present moment appears opportune for the purpose of briefly reviewing the most recent examples of locomotive practice on British railways and for referring to certain developments known to be forthcoming. The latest engines in actual service at the time of writing are those designed by Mr. H. A. Ivatt for the Great Northern Railway, and by Mr. George Whale for the London and North Western Railway. The illustrations, Figs. 1 and 2, show the first-named engine. In this design Mr. Ivatt has departed from his previous practice on the Great Northern by resorting to the use of compound cylinders, but he has done so whilst retaining the majority of the features and many of the dimensions of his existing locomotives of the "251" class.*

In both cases the engines are of the "Atlantic" (4-4-2) type and the boiler is identical in the two designs, as regards overall dimensions, the only difference of any importance being that slightly thicker plates are used for the compound, owing to the higher steam pressure carried, viz., 200 lbs. per square inch, as against 175 lbs. in the "251" class engines.

It is to be remarked also that the total wheelbase remains the same in the new engine as in the previous ones, although it might have been expected that the front pair of coupled wheels—the low-pressure drivers—would have been set further back from the bogie, to allow of longer inside connecting rods being used.

Although it would have been possible to do this, whilst still avoiding any increase in the total wheelbase, it would have had the effect of adding length to the outside main rods—already over 10 ft. long—and would have necessitated alterations in the design of the fire-box and re-arrangement of the carrying wheels under the cab.

NOTE.—*The Editor is specially desirous that the above, which will be continued each month, should constitute a authoritative survey of the latest developments in railway engineering matters, and manufacturers as well as officials of railway engineering departments are cordially invited to communicate particulars of recent work.*

Communications should be addressed The Editor, Railway Section, "Engineering Review."

* Fully illustrated in *The Engineering Review*, for February, 1904.

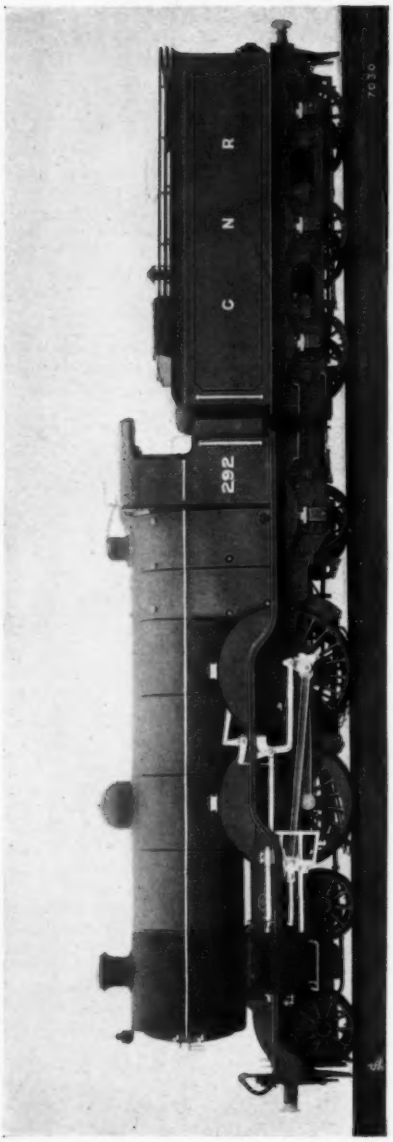


FIG 1.—FOUR-CYLINDER COMPOUND EXPRESS PASSENGER LOCOMOTIVE, GREAT NORTHERN RAILWAY.

This would have interfered with the present method of weight distribution, which has been found to give very satisfactory results. As matters stand, the total wheel-base of the engine is only 26 ft. 4 in., the shortest of any 4-4-2 type locomotive running in this country.

Briefly, the engine is a four-cylinder compound, with the cylinders arranged in line below the smoke-box; two, the high-pressure, outside the frames driving the second pair of coupled wheels, whilst the low-pressure are located between the frames and drive the crank axle of the leading pair. Steam is distributed to the outside cylinders by means of Walschaert's valve gear, actuating balanced slide valves of the open-backed type working above them. Ordinary link motion is employed for the low-pressure cylinders, and in this case the valves work at the side of the ports, the steam chest being located between the cylinders. There are two reversing levers, with sectors placed close together on the footplate and the two sets of reversing gear can be operated either simultaneously or independently of one another, as may be desired. Each reversing shaft is fitted with a vacuum lock at the centre, by means of which the gear can be locked close to the work, thus overcoming the effect produced by slackness between the shaft and the footplate mechanism. The engine can be worked either as a simple or as a compound; a change valve located over the low-pressure steam chest allowing of this. The valve is worked by a small auxiliary steam cylinder in connection with a water dash-pot arranged so as to lock it either in the simple or compound position. The engine is slightly heavier than those of the "251" class, viz., 109 tons 18 cwt., as compared with 105 tons. This is accounted for by the presence of the additional cylinders, rods, and valve gear, whilst the boiler, owing to the thicker plates, is also slightly heavier. The principal dimensions of this interesting design are as follows:—

Cylinders h.p. (2) outside ...	13 in. dia. × 20 in. stroke.
„ l.p. (2) inside ...	16 in. dia. × 26 in. stroke.
Coupled wheels	6 ft. 8 in. dia.
Coupled wheelbase	6 ft. 10 in.
Total wheelbase	26 ft. 4 in.
Boiler, dia. outside	5 ft. 6 in.
„ length between tube plates	16 ft.
„ height of centre from rail	8 ft. 8½ in.
Heating surface (total) ...	2,500 sq. ft.
Grate area	31 sq. ft.
Working steam pressure ...	200 lbs. per sq. in.
Weight (engine only) loaded	69 tons.
Adhesion weight	36½ tons.

A standard Great Northern Railway six-wheeled tender is fitted, having capacities

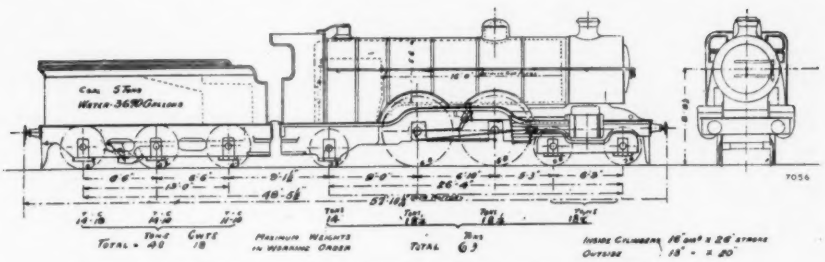


FIG. 2.—FOUR-CYLINDER COMPOUND EXPRESS LOCOMOTIVE, GREAT NORTHERN RAILWAY.

for five tons of coal and 3,670 gallons of water. Its weight fully loaded is 40 tons 18 cwts., and it is fitted with water pick-up apparatus. The locomotives of this class are intended for working the heaviest express passenger trains, and their working should provide useful data for comparison with the performances of other engines on the same duty.

The London and North Western Railway engine is illustrated in Fig. 4. As will be seen, it is of the 4-6-0 type with inside cylinders. The design may be regarded as the counterpart of Mr. J. F. McIntosh's engines of the same class on the Caledonian Railway. In respect of general outline as well as of detailed construction the new engine, and others of the same series, follow the lines of Mr. Whale's "Precursor" class locomotives of the 4-4-0 type on the London and North Western Railway, the principal difference between the two designs being in the number and diameter of the coupled wheels. The boiler is of necessity longer in the engine illustrated than in the "Precursor" class, but in other respects it conforms to the proportions of the earlier design. The new engines are intended specially for working the heavy trains of 300 tons on the northern sections of the London and North Western main line, between Crewe, Preston and Carlisle, without the assistance of a pilot engine, and it seems more than likely, judging from the dimensions given herewith, that they will prove equal to the task. The leading dimensions are as follows:—

Cylinders	19 in. by 26 in.
Coupled wheels	6 ft. 3 in. on tread.
Rigid wheelbase	13 ft. 7 in.
Total wheelbase	26 ft. 8½ in.
Total heating surface	2041 sq. ft.
Grate area	25 sq. ft.
Weight of engine in working order	65 tons 15 cwts.

The first of the new 4-6-0 type passenger locomotives designed by Mr. Dugald Drummond, Chief Mechanical Engineer London and South Western Railway, is, at the time of writing, nearing completion at the company's Nine Elms shops, and will shortly be ready for service.

In this case there are four simple cylinders arranged in a similar manner to the de Glehn system compound locomotives, viz., with one pair of cylinders outside the frames to the rear of the bogie, and the other pair between the frames, below the smoke box. The outside cylinders drive the intermediate pair of coupled wheels,

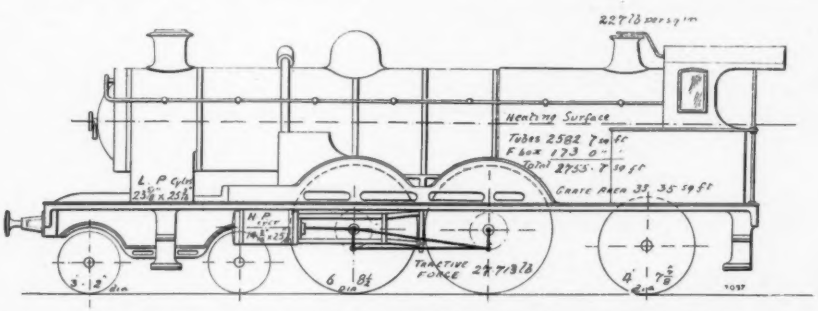


FIG. 3.—DIAGRAM OF NEW DE GLEHN COMPOUND LOCOMOTIVES, GREAT WESTERN RAILWAY.

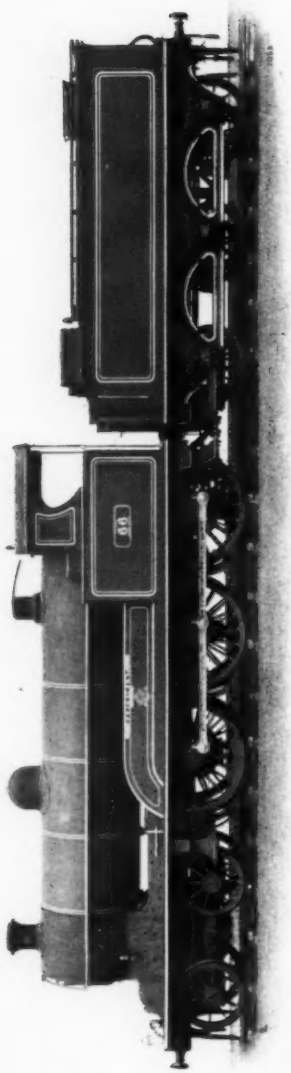


FIG. 4.—4-6-0 TYPE PASSENGER LOCOMOTIVE, LONDON AND NORTH-WESTERN RAILWAY.

while those inside drive the crank axle of the foremost pair. Steam is distributed to the outside cylinders through the medium of Walschaert's valve gear, but ordinary link motion is employed for the others. The four cylinders will, in the aggregate, be equal to two of 22 in. diameter by 26 in. stroke, and these in conjunction with three pairs of coupled wheels, 6 ft. in diameter, ample heating surface, and a high steam pressure, will go to make up an unusually powerful engine, and one which should be able to perform the heaviest duty in a satisfactory manner. A very large boiler is provided, having a total heating surface of about 2,700 square feet. This is partly contributed by a number of cross water tubes in the fire-box. The heating surface of the fire-box itself, apart from these water tubes, is a large one, and as the boiler tubes are only 14 ft. in length it will be at once recognised that the whole of the total area of 2,700 square feet will be accessible to the furnace gases whilst at a high temperature, and thus of first rate value.

The smoke-box contains Mr. Drummond's patent spark arresting and fuel economising device as in the case of all South Western locomotives. The new engines far surpass in power any previously in use on this railway. They will be put to work on the principal main line services as completed.

On the neighbouring line, the London, Brighton and South Coast, the newly-appointed locomotive engineer has already put in hand at the works of Messrs. Kitson and Co., Leeds, some heavy "Atlantic" type locomotives similar to those of the "251" class on the Great Northern Railway. It is as yet too early to give the dimensions, but it is understood that the engines will be approximately equal in size and power to those on the Great Northern Railway.

On the Great Western Railway Mr. G. J. Churchward is adding to the number of 4-4-2 and 4-6-0 type locomotives, whilst the two additional de Glehn compounds have now been completed and despatched from Belfort to this country. They are of larger dimensions than the existing French compound on the Great Western, as the following comparative figures will show:

	New Engines.	"La France."
Cylinders (2) h.p.	14$\frac{7}{16}$ in dia.	13$\frac{3}{8}$ in. dia.
,, (2) l.p.	23$\frac{3}{8}$ in. dia.	22$\frac{1}{16}$ in. dia.
Heating surface (tubes) ...	2582·7 sq. ft.	2288·77 sq. ft.
,, ,, (fire-box)	173·0 sq. ft.	167·00 sq. ft.
,, ,, Total ...	2755·7 sq. ft.	2455·77 sq. ft.
Grate area	33·35 sq. ft.	29·5 sq. ft.
Working steam pressure	227 lbs.	227 lbs.
Tractive force	27·713 lbs.	24·382 lbs.

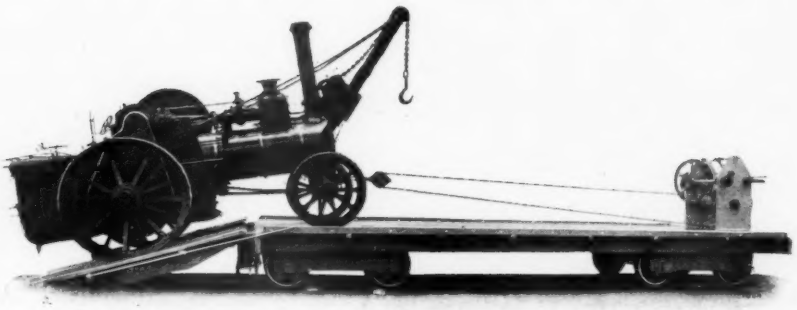


FIG. 5.—SPECIAL TRANSPORT WAGON BY THE LEEDS FORGE COMPANY.

On the Great Central a 4-4-2 type locomotive is being adapted for working on the Smith system of compounding, with three cylinders, viz., one high and two low pressure. In all other respects this engine and any others built on the same principle will be identical with Mr. Robinson's existing Atlantic type locomotives with 19½in. by 26in. single-expansion cylinders on the Great Central Railway. The de Glehn four-cylinder compound locomotive building at the works of the Vulcan Foundry Co., Ltd., of Newton-le-Willows, for the Great Northern Railway, is expected to be in regular service within the next few months.

Special Type of Transport Wagons for an Egyptian Railway.

THE Leeds Forge Company have recently constructed eight bogie wagons of a special type designed for transporting one of Messrs. Fowler's steam ploughing engines, or when required, one of their ploughs or cultivators. These wagons have been built for use on a private railway in Egypt, and are shown in the accompanying illustration. Each wagon is provided with an end ramp hinged to the headstock of the underframe, which can be lowered on to the rails, and a hand winch on the other end of the wagon is used for hauling the engine or ploughing machine on to the wagon or removing it therefrom.

When the wagons are running the ramp is raised into a vertical position, and there secured by stays. The buffers on the ramp end of the underframe are hinged at the bottom, so that by removing a cotter at the top they will drop out of the way of the ramp. Struts are also placed under this end of the wagon, which require to be adjusted slightly above the rail level to take a portion of the weight while the engine is over the same, thus preventing the underframe being strained through the whole of the weight being thrown upon one bogie. It is not, however, necessary to use these struts when the plough or cultivator is being placed on the wagon, as these machines are, of course, considerably lighter than the engine. The struts can be placed out of the way on a hook under the headstock when the engine is running.

The method of raising and lowering the end ramp consists in passing the rope from the winch through a snatch block which is attached to the underframe, and then over struts on the ramp, which struts can be lowered to the level of the ground when the engine is being hauled up the ramp. The same snatch block is also used for attaching to the engine, and the rope is passed through the same and back to a hook under the winch in order to give sufficient power for lifting the engine. The winch is designed to give a pull of three tons from the barrel when working in double purchase, *i.e.* a total pull of six tons is available when using the snatch block on the engine for hauling the latter on to the wagon. The weight of the ploughing engine is twenty-two tons.

On testing one of these wagons in the builders' works it was found that the time occupied in lowering the ramp, hauling the engine on to the wagon, and again raising the ramp into its running position was less than thirty minutes, and it is certain that when the men become accustomed to the various manœuvres considerably less time than this would suffice for the purpose. The bogies for these wagons are constructed of

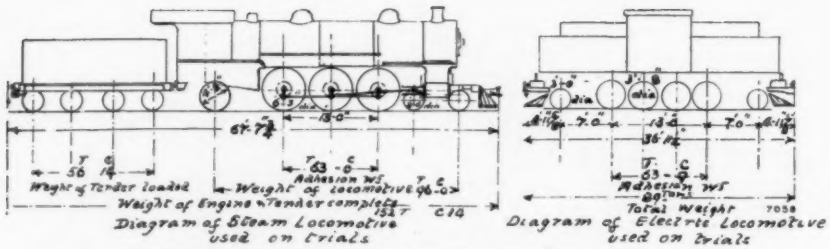

Weight of Tender loaded
Weight of Engine + Tender complete
Diagram of Steam Locomotive used on trials
Adhesion Wt.
Weight of locomotive
Total Weight
Diagram of Electric Locomotive used on trials

FIG. 6.—ACCELERATION TESTS, NEW YORK CENTRAL AND HUDSON RIVER RAILROAD.

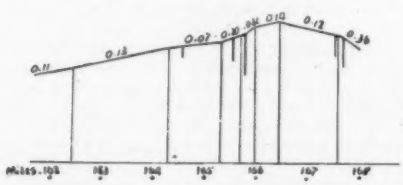
Fox's pressed steel frame plates. The writer is indebted to Messrs. the Leeds Forge Co., Ltd., for the foregoing particulars and photograph.

Acceleration Tests on the New York Central and Hudson River Railroad.

SOME interesting tests were made a short time since in the United States for the purpose of comparing the acceleration powers of a steam locomotive belonging to the New York Central and Hudson River Railroad with those of an electric locomotive supplied by the General Electric Company of Schenectady, New York. The trials were carried out on a length of track measuring six miles and laid with 80 lb. rails. Gradients of 5 ft. to 19 ft. per mile and curves of 2 deg. 17 min. among others are included in the length selected, whilst the longest tangent measures 7,565 ft. The steam locomotive was of the "Pacific" (4-6-2) type, weighing, in working order, 96 tons, 14 cwts., with 63 tons available for adhesion. The electric locomotive ran upon twelve wheels, eight of which were drivers. Of the total weight of 89 tons, 63 tons 9 cwt. rested on the driving axles. The trains hauled varied in composition, consisting sometimes of six and at other times of eight cars. In the latter case the weight of train was 513 tons, and, in the former, 407 tons for the electric and 427 tons for the steam train. In spite of its weighing less by 20 tons, the electric train accommodated an appreciably greater paying load than its rival. The following particulars, together with the outline drawings reproduced herewith, will present an accurate idea as to the varying proportions of each equipment.

	Steam Locomotive and Train.	Electric Locomotive and Train.
Length of locomotive overall...	67 ft. 7¾ in.	36 ft. 11½ in.
Total weight (with tender)	152 tons, 14 cwt.	89 tons.
Maximum load on one axle	21 tons.	15·85 tons.
Paying load (of train) ...	256 tons.	307¼ tons.
Average acceleration up to 50 miles per hour in miles per hour per second	0·246	0·394
Time taken to reach 50 miles per hour ...	203 secs.	127 secs.

It was found that in some cases the steam locomotive, when hauling the eight car trains, accelerated faster than the electric locomotive at the outset, and this was attributed to the fact that the temporary conductor used for supplying the current for the electric train had an insufficient area, the voltage drop in this being from 700 down to 325 volts. The average rate of acceleration up to the maximum speed was, however, substantially greater in the case of the electric locomotive. The latter running light attained a maximum velocity of 85 miles per hour.



PROFILE OF TEST TRACK, SIX MILES IN LENGTH.

New Tank Engines for the Rhymney Railway.

MESSRS. ROBERT STEPHENSON & CO., LTD. recently supplied from their works at Darlington six 0-6-2 class radial tank engines of a new type to the Rhymney Railway. The engines have inside cylinders and large boilers fitted with Belpaire pattern fireboxes and are generally up to modern specifications throughout. The design will be illustrated and the principal dimensions given in a later issue.

Electrical Notes.

By ANDREW STEWART, A.M.I.E.E.

Some Recent Electric Locomotives.

TEN electric locomotives weighing 150 tons, and having a normal rating of 1,200 h.-p., are being supplied by the British Westinghouse Company for the Metropolitan Railway; one of them has now been delivered, and is illustrated, Fig. 1. These locomotives are equipped with four motors each of 300 h.-p., and in order to keep them as small as possible, forced ventilation has been adopted. These locomotives will be employed to haul trains of approximately 120 tons, at a speed of 36 miles per hour on the level, and are intended for hauling goods trains and passenger trains of other companies whose lines are not electrified. For instance, the London and North Western trains between Mansion House and Willesden will be hauled by these electric locomotives from Mansion House to Earl's Court, where the train will be taken over by a steam locomotive; the same applies to the Harrow and Baker Street line. Beyond Harrow the trains are hauled by steam locomotives and taken over by electric locomotives at Harrow, where the journey is completed over the electrified portion.

An interesting locomotive, also by the British Westinghouse Company, is the 25-ton single-phase locomotive, built for the Swedish State Railways, which is chiefly remarkable for the fact that it is designed to operate with a trolley pressure of 18,000 volts, though it may be operated at any voltage down to 3,000. The locomotive carries an oil-cooled auto-transformer (for connections of auto-transformer see ENGINEERING REVIEW, p. 735), and an oil break circuit breaker. The control is electro-pneumatic, and consists of an air compressor driven by a single-phase motor, an air motor on the induction regulator, air cylinders on the circuit breaker and reverser. This air compressor also supplies the air brakes and air sanders. Two locomotives may be coupled together and operated by one controller. Two 150 h.-p. 25-cycle single-phase motors are geared, one to each axle, by spur gear having a ratio of reduction of 3·9 to 1. The driving wheels are 41 in. in diameter. They are designed to handle 70-ton trains at 40 miles per hour, and it is the intention of Mr. Robert Dahlander, Director of the Electrical Department, Swedish State Railways, to carry out exhaustive experiments on the application of electric power to the main lines.

Another electric locomotive, more powerful than either of the foregoing, is the 135-ton electric locomotive, recently built at the Baldwin Locomotive Works and equipped by the Westinghouse Company, for the purpose of hauling heavy freight trains. It differs from Fig. 1 in that the centre cab is carried from end

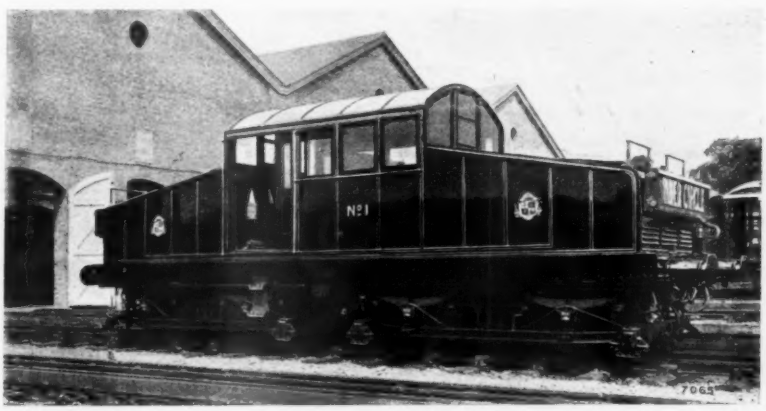


FIG. 1.—150 TON ELECTRIC LOCOMOTIVE FOR THE METROPOLITAN RAILWAY.

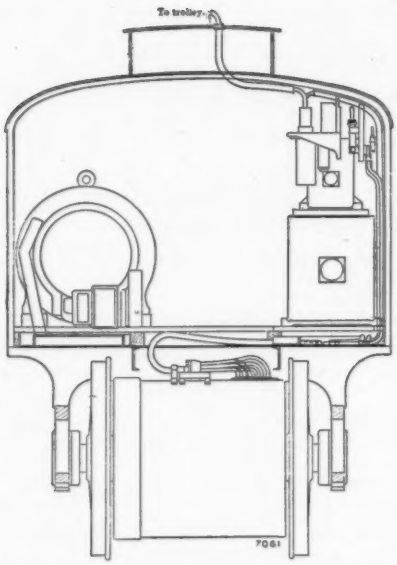


FIG. 2.—SECTION THROUGH 135 TON SINGLE-PHASE ELECTRIC LOCOMOTIVE.

to end and is built in two halves, either of which can be used independently of the other should necessity arise. It is designed for a trolley voltage of 5,000 to 6,000 volts, which is reduced to 225 at the motors. Each end is carried on two six-wheeled trucks, which have a rigid wheel base. These wheels, all of which are drivers, are 5 ft. in diameter, and mounted on 8-in. axles, the distance between centres being 6 ft. 4 in. The side frames are of cast steel and spring supported, the cabs are of sheet steel on angle iron supports, and the entire cab is removable from the truck. Each axle carries a 225 h.-p. single-phase series motor (see section Fig. 2), so that the total h.-p. is 1,350, but the locomotive can exert considerably more power on emergency. As in the Metropolitan Railway locomotives, forced ventilation has been adopted in order to keep down the size of the motors. With the locomotives at full power a draw bar pull of 50,000 lbs. was exerted at 10 miles per hour; when hauling a train weighing 1,200 tons steady draw bar pulls of 60,000 to 65,000 lbs. were recorded, and momentary pulls of 100,000 lbs. were also reached. The spectacle of such a large locomotive drawing its power from a trolley wire ·4 in. diameter interested those watching the tests, as showing the flexibility of the high pressure alternate current system, and demonstrating the ease with which large powers could be supplied to electric locomotives.

Electric Lighting of the Hamburg-American Liner "Deutschland."*

THIS liner has 2,250 glow lamps and 23 electric motors driving auxiliary machinery. The generating plant consists of three 77 kilowatt and two 44 kilowatt generators driven by vertical compound engines. The principal dynamo room is located aft the main engine room, between the two propeller shafts, though one dynamo is located in a small room on the main deck above the water level. The main cables are rubber insulated with lead covering and iron wire armour. All the signal and other lights are electric. In order that the officer on duty may be acquainted with the condition of the masthead and other lights, an electro-magnetic arrangement connected to these lights is arranged on the bridge deck in such a manner that immediately the light is extinguished a light of corresponding colour is extinguished on this electro-magnetic device. More than half the motors are directly connected to fans and blowers, the stoke hold fans are bolted to the roof and the motors are upside down. Notwithstanding the large quantities of coal dust their performance is very satisfactory. There are coal elevators, as well as conveyors for parcels, provisions, &c., driven by electric motors. In addition a kneading machine is driven through worm gearing by a motor which is operated by the ship's confectioner. In the engine room there are two electrically driven drilling machines, and portable drills for executing repairs during the voyage.

High-Speed Long-Distance Electric Railways.†

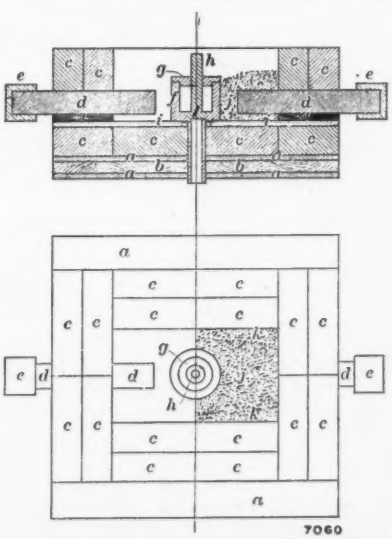
THIS paper, by Mr. C. A. Mudge, formerly chief engineer of the railway department of the Allgemeine Elektricitäts Gesellschaft, Berlin, who participated in the well-known Marienfeld-Zossen high speed trials, dealt with some of the problems to be met and overcome in connection with such lines. The equipment supplied by the Allgemeine Company differed from that of Messrs. Siemens & Halske, but the former only was dealt with, though most of the conclusions are of general application. The A.E.G. car was 69 ft. long by 9¼ ft. wide, divided into three compartments, one in the middle was 12 ft. long and contained the starting rheostat and high potential switches; it was always unoccupied when current was on. Of the other two compartments, one was for measuring instruments and the other for passengers. Under the car floor were the transformers for reducing the line pressure of 14,000 volts to that required in the motors. The six-wheel trucks carrying the car were spaced 43 ft. 7⅛ in. from the centres, the

* *Electricity*. New York, June 7th.
† *Abstract of a Lecture to the New York Electrical Society*. *Electrical Review*. New York, June 10th.

driving wheels had a diameter of 49$\frac{3}{16}$ in. and a wheelbase of 6 ft. 3 in., which was subsequently increased to 8 ft. 2$\frac{1}{2}$ in. The car weighed 100 short tons, which, however, was raised to 104 tons during later experiments, owing to the necessity of introducing additional weights to counteract the swinging lateral motion which became serious at high speeds. This swinging motion was found to be due to the unequal disposition of the weight of the equipment. After these correcting weights had been introduced, the car ran as smooth as a Pullman, even at 125 miles per hour. Before being placed on the experimental line the car was drawn about 500 miles by a steam locomotive to loosen the running parts. The general results of the tests were as follows:—At 50 miles per hour the maximum air pressure on the front of the train is about 7 lbs. per sq. ft., at 100 miles per hour the air pressure is four times as great, at 150 miles per hour the pressure is nine times as great. A reduction of 10 per cent. may be effected in the air pressure if the nose of the car is properly shaped. A 100-ton car at 50 miles per hour takes 150 h.-p. on a level track, at 100 miles per hour the power required becomes 900 h.-p.; and at 150 miles per hour the power required becomes 2,700 h.-p. The trolleys worked well, but towards the end it became apparent that more substantial trolley construction would be necessary for commercial high speed lines. Braking was unsatisfactory, the enormous pressure available at high speeds giving only low retardation. The following is a summary of Mr. Mudge's points:—(1) Keep the car body as close to the rails as possible. (2) Arrange heavy apparatus so that their centres of gravity lie in the centre of the car, or in symmetrical relation therewith, and as near the rail level as possible. (3) Apparatus mounted above the car floor to be as light in design as possible. (4) The current collecting gear should be above, not on the side of the car (the current collecting gear was on the side at the Marienfeld trials). (5) Adopt flexible suspension for the motors; this is due to the fact that the natural oscillations of the car do not always synchronise with the forced oscillations due to the inequalities of the road-bed, a small amount of flexibility greatly reduces the force of the blows which the equipment of the car experiences under these circumstances. At speeds over 100 miles per hour it often seemed that there was no rolling friction, and that the car was floating; then it suddenly appears as if the car descended once more on the rails: at these points it seems as if the equipment does not descend with the car, and the latter experiences violent shocks, which can only be cushioned by flexible suspension. (6) Give the front of the car a wedge shape. (7) Support the car body on the truck frame at some distance from the centre bolt, and allow it some flexibility at right angles to the track. (8) Make the wheel base of the truck not less than 20 per cent. of the length of the car. (9) Straight tracks are desirable, and where double, each track must be further apart than at present. (10) On curves make the approaches of the elevated side of the track longer than present practice. If it were possible to have the wheels on the side of the car and the rails between the roof and floor of the car, high speed travel would be more comfortable. It is impossible to recognise signals at speeds over 125 miles per hour on dull or wet days. Electric signals on the car were tried successfully. During the discussion Mr. F. J. Sprague said that taking into account practical conditions 100 miles per hour was as much as engineers could reasonably try to reach. Mr. C. O. Mailloux thought that the substitution of electricity for steam would be effected by an evolutionary, and not a revolutionary process, and that 25 years hence there would still be steam locomotives.

An Electric Furnace Producing Diamonds.

MR. HENRY W. FISHER recently read a paper to the Pittsburg Academy of Science and Art, describing some of his experiments with an electric furnace for the above purpose. His first furnaces were of lime, like those of Moissan, but they were unsatisfactory, so also were furnaces of asbestos with a heavy lining of magnesia blocks. The final design is shown in Figs. 3 and 4. *a a* is asbestos above and below the table, *b*; *c c* are fire bricks; *d d* graphite electrodes; *e e* castings of brass over the ends



FIGS. 3 AND 4.—ELECTRIC FURNACE FOR DIAMONDS.

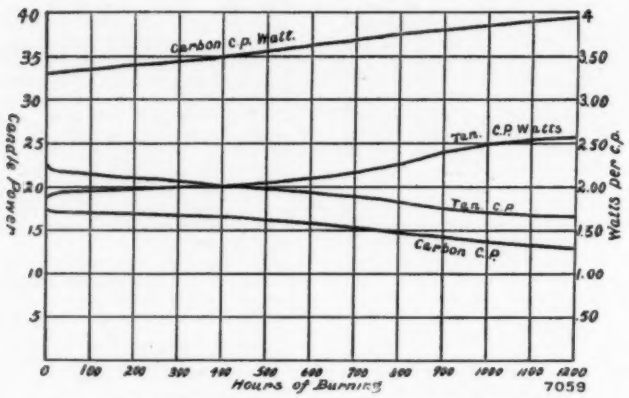


FIG. 5.—PROGRESS IN INCANDESCENT LIGHTING. CANDLE POWER CURVES.

of the electrodes; *i i* a lining of magnesite; *f* is the crucible, part of which extends through the table; *g* is the cover of the crucible, and *h* is a valve stem which can be lifted to allow the contents of the crucible to fall into the cooling

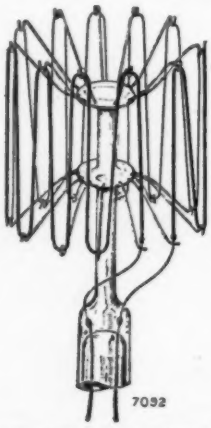


FIG. 6.—FILAMENT OF TANTALUM LAMP.

chamber below; *f g* and *h* are made of pure graphite, and *j* is crushed coke placed in the crucible around the electrodes, the portion at the end of the electrode being finely divided so as to insure fairly uniform distribution of heat. Fig. 2 is a plan looking down from the top of the furnace, the same letters being used as above to designate the different materials. At each side of the graphite, *j*, is a lining of magnesite, *k*, which is broken into fine pieces, this material is an excellent insulator of heat, and being powdered does not conduct much current when the furnace is hot. The chief difficulty experienced was in cooling the matrix with sufficient rapidity, and the final solution of the difficulty was to drop the crucible into water through the bottom of the furnace The diamonds produced were satisfactory though small. The energy used amounted to about 50 kilowatts (67 h.-p.), and the current 1,200 amperes. The temperature could not be measured exactly, as the pyrometer reached its maximum of 1,950° C. long before the greatest heat was reached, and it is estimated that the temperature of the matrix was 2,500-2,800° C., though in parts the temperature probably was as high as 3,500 to 4,000° C. Mr. Fisher stated that he would experiment with another process not involving heat, whereby larger diamonds might be made.

Progress in Incandescent Electric Lighting.

THE carbon filament glow lamp with which we are all familiar, seems likely to be superseded at no distant date by much more efficient lamps. It has long been known that the most

FIG. 7.—OSMIUM LAMP.

economical lamp is the lamp whose filament will stand the highest temperature, and the fact that a few rare metals will stand temperatures of considerably over 2,000° C. has also been known. The task of finding one which, while withstanding high temperatures, can be worked into a convenient filament, has been undertaken by several investigators. As a result glow lamps have recently been placed on the market, having filaments made of osmium and tantalum. The former is one of the most infusible of platinum metals, and one of the heaviest of all bodies, having a specific gravity of 22·48; the latter is a rare metallic element discovered in the Swedish minerals tantalite and yttro tantalite. Both these lamps have recently attracted much attention, chiefly by reason of the fact that they are much more economical than carbon filament lamps. Fig. 5 shows the results of the tests made by Dr. Louis Bell and Prof. W. L. Puffer* on a tantalum lamp and an ordinary carbon filament lamp. The superiority of the new lamp will be evident, the watts per candle power starting at 1·8, and reaching 2·6 at the end of a 1,200 hour run, while the carbon filament lamp starts at 3·4 and finishes at 3·9. It is interesting to note that the drop in candle power with age is similar in each case. As the tantalum filament has a much lower resistance than a carbon filament, a much greater length has to be used. In a standard 110 volt, 25 Hefner candle power,* lamp the filament is about 25½ in. long and supported by umbrella shaped supports, Fig. 6. As the lamp is used the filament contracts slightly and becomes strained rather tightly over the supports. The 25 candle power filament already referred to has a diameter of ·05 mm. and a weight of ·022 grammes, so that 20,000 lamps could be made from 1 lb. of the metal. The lamp can be used in any position, and gives a white light. The osmium lamp is the invention of Herr Auer Von Welsbach, and has been in a more or less experimental form for about six years. It is said to be slightly more efficient, consuming about 1½ to 1¾ watts per candle power, It also suffers from the disadvantage of requiring a very long filament, a 25 candle power (Hefner) 37 volt lamp having a filament 11 in. long and ·087 mm. diameter, they are generally made for such low voltages, and several are grouped in series on high voltage circuits. A life of 5,000 hours has been exceeded, and in this respect the osmium lamp has no rival, though apparently the manufacturers do not guarantee this life. In this connection it was stated at a meeting of the Elektrotechnischer Verein, Berlin, that a life of 14,000 hours had been reached. An osmium lamp is shown in Fig. 7.

* *Electrical World and Engineer*. New York, June 3rd.

* One Hefner candle power = ·885 British c.p.

CATALOGUES AND TRADE PUBLICATIONS.

B. J. Hall & Co., 39, *Victoria Street, S.W.*—Catalogue of drawing office specialities, containing a complete selection of instruments and materials of various qualities suited to the use of the expert and the beginner.

Peckett & Sons, Atlas Locomotive Works, Bristol.—Abridged list of tank locomotives which is the firm's exclusive speciality, and are manufactured and adapted to meet the severe requirements for the work required to be done on branch and mineral lines, at collieries, iron-works, &c.

Holden and Brook, Ltd., Manchester.—Abridged catalogue of appliances and steam fittings for power plants.

W. & T. Avery, Ltd., Soho Foundry, Birmingham.—Catalogue No. 221, dealing with testing machinery of every description, including that for testing transverse bar, cast iron, spring chain, cement, yarn; also hydraulic and torsion machines. The brochure is prefaced by some useful hints on testing cast iron.

Masons Gas Power Co., Ltd., Alma Works, Levenshulme, Manchester.—A well got-up book, dealing with this firm's specialities in producer gas plant, and containing full descriptions of their Duff and Whitfield Patent Gas Producers, together with a note on producer gas and its applications.

R. Y. Pickering & Co., Ltd., Wishaw, N.B.—Booklet containing illustrations of types of railway carriages, wagons and wheels made by this firm within the last few years.

Ruston, Proctor & Co., Ltd., Lincoln.—Illustrated album of the new boiler works just erected, giving a record of the works, the up-to-date machinery and appliances installed therein, and illustrating boilers of various classes in their different stages of construction.

W. Summerscales & Sons, Ltd., Phœnix Foundry, Keighley.—Catalogue No. 673, of high-class modern laundry machinery and steam cooking apparatus. An illustration of a steam laundry recently fitted up is given, together with a general review of the working of same.

METALLURGICAL PROGRESS

By PERCY LONGMUIR,

Carnegie Research Medallist.

General Metallurgy.

*Electricity in Metallurgy.**—Mr. de Neufville has in a recent address at Frankfort, discussed the application of electricity to metallurgy. The relatively high cost of energy renders this application advisable only when valuable products can be obtained from rich materials. In the production of gold from ores, large quantities of material containing no gold have to be treated, hence the electric process does not pay. Electrolytic separation of gold from a solution of cyanide of potash is, however, profitable. Electrolytic refining of silver is in general use, and refining by acids is in vogue only where the material treated is rich in gold. Electrolytic processes for obtaining copper from its ores have failed from commercial rather than technical difficulties. Electrolytic refining of copper is, however, widely used. Electrolysis has of late been employed in refining lead, the object being to procure lead entirely free from bismuth. Smelting processes are still maintained for nickel, and only in refining has electrolysis been profitably used. Electrolytic works for zinc have not been profitable, but electro-thermic processes for the production of this metal may become of greater importance. For iron and steel the electrolytic process is too costly, and the electro-thermic processes are more likely to be successful.

Electrolytic Treatment of Electrolytic Slime.†—At the outset Mr. A. G. Bett discusses electrolytic slimes and the metals recoverable from them. The advantages of electrolytic treatment are simultaneous regeneration of the solvent, H_2SO_4, and of the oxidising agent at a lower cost than for new chemicals; recovery of the copper as electrolytic copper, the conversion of outside copper oxide into metal; the recovery of arsenic as arsenious acid, and of antimony and bismuth as metals.

An outline of the process is shown in Fig. 1. The ferric sulphate solution as it comes from the electrolytic tanks, contains 4 to 5 per cent. of iron as ferric sulphate, 0·5 to 1·0 per cent. as ferrous sulphate, 1 per cent. copper as cupric sulphate, and from 4 to 6 per cent. of free sulphuric acid. The solution is agitated in a lead-lined tank, and copper oxide added, which rapidly dissolves. The slime for treatment is then added and the following reactions take place:—

$$Cu + Fe_2(SO_4)_3 = Cu\,SO_4 + 2\,Fe\,SO_4$$
$$Pb + Fe_2(SO_4)_3 = Pb\,SO_4 + 2\,Fe\,SO_4$$
$$2\,As + 3\,H_2O + 3\,Fe_2(SO_4)_3 = As_2O_3 + 6\,Fe\,SO_4 + 3\,H_2SO_4$$
$$2\,Sb + 3\,H_2O + 3\,Fe_2(SO_4)_3 = Sb_2O_3 + 6\,Fe\,SO_4 + 3\,H_2SO_4$$
$$2\,Bi + 3\,H_2O + 3\,Fe_2(SO_4)_3 = Bi_2O_3 + 6\,Fe\,SO_4 + 3\,H_2SO_4$$
$$2\,Ag + Fe_2(SO_4)_3 = Ag_2SO_4 + 2\,Fe\,SO_4$$

The acid set free by the oxidation of arsenic, antimony and bismuth, is neutralised by copper oxide before treating a second batch, in order that the process may be regenerative.

Any dissolved silver in the bath is precipitated by hanging copper plates in the solution. The residue is washed free from iron and copper solution on its passage through a filter press. The further treatment of these cakes and of the solution is indicated in the diagram Fig. 1.

*Pipe Manufacture by Continuous Process.**—This process, patented by Stravs and Jager, claims to produce by centrifugal force pipes and hollow ingots from fluid metal. The apparatus shown in Fig. 2 is designed for the production of 3-in. lead pipe of any desired length. The mould A is connected to the tubular support B which is provided with driving gear and supported upon anti-friction bearings. The upper part of the mould has a distributing chamber C with a plunger D having a valve E that nearly closes the top of the mould. Fluid metal is fed from the chamber C into the top of the mould around the edge of the valve E. The plunger D has a tubular stem extending through the support B which serves to rotate the plunger and to adjust the position of the valve E. For the purpose of permitting molten lead to pass into the chamber C the plunger stem has a series of openings F and a disc G. The

* *The Mining World.* Vol. xxii., No. 13.
† *Electro-Chemical and Metallurgical Industry and Mining World.* Vol. xxii., No. 20.

* *Iron Trade Review.* Vol. xxxviii., No. 18.

metal enters through a stationary tube H which is electrically heated and covered with non-conducting material. In the lower part of the mould is a support I which carries the lower end of the pipe being formed. During the formation of the pipe this support gradually descends and is rotated simultaneously with the mould. A high temperature is maintained by means of coils J; on completion of the pipe its temperature is lowered by the cooling chamber L through which water circulates, and by these means the pipe material passing along the inner surface of the mould is solidified. The thickness of the pipes is determined by the amount of metal admitted and by the velocity of the support I which, if rapid, results in a thin walled pipe and *vice versâ*.

For metals of higher melting points the chamber and part of the mould are lined with siloxicon, a refractory lining which has proved most serviceable. For some purposes the pipes may be reinforced by wire, and an arrangement may be attached for automatically feeding in wire during the formation of the pipe.

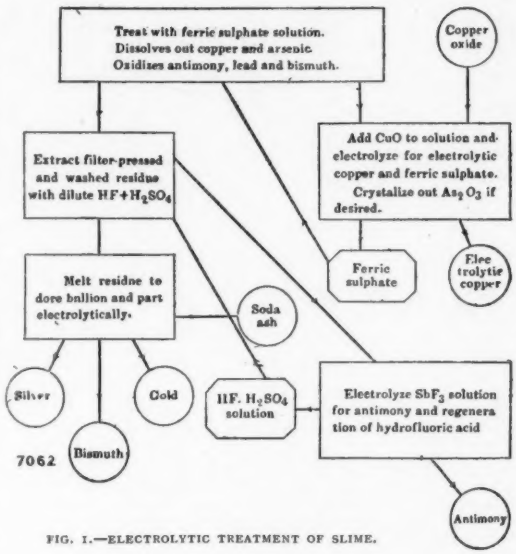

Treat with ferric sulphate solution. Dissolves out copper and arsenic. Oxidizes antimony, lead and bismuth.
Copper oxide
Extract filter-pressed and washed residue with dilute $HF+H_2SO_4$
Add CuO to solution and electrolyze for electrolytic copper and ferric sulphate. Crystalize out As_2O_3 if desired.
Ferric sulphate
Electrolytic copper
Melt residue to dore bullion and part electrolytically.
Soda ash
Silver
Gold
Bismuth
7062
HF. H_2SO_4 solution
Electrolyze SbF_3 solution for antimony and regeneration of hydrofluoric acid
Antimony

FIG. 1.—ELECTROLYTIC TREATMENT OF SLIME.

*High Temperature Measurements.** — In this article, Mr. S. H. Stupakoff discusses optical pyrometers, indicating their application and describing various types. The Holburn-Kurlbaum type is sketched in Fig. 3, and the following is a brief description of the pyrometer. An image of the hot incandescent body under observation is formed in the focal plane of the objective where is found the filament of a small 4-volt lamp. The current through the filament is varied until the tip is of the same colour as the incandescent body when it will completely merge with it and fade from view. The current through the milliammeter is then a measure of the temperature if the instrument has been properly calibrated.

Copper, Tin and Oxygen.†—In his second article Mr. O. Bauer‡ examines in further detail the occurrence of tin oxide in bronze. The formation of tin oxide, when copper, copper oxide and tin are melted under conditions which preclude external oxidation is as follows:—

$$2\,Cu_2O + Sn = 4\,Cu + SnO_2$$

Full experimental results are given showing that under these conditions copper oxide is reduced to metallic copper with the consequent oxidation of tin. Turning to the practical side of a somewhat lengthy paper it is shown that the deterioration of bronze by remelting is due to this oxidation of tin. Chemically this oxide is not detected, for under ordinary conditions of analysis it is reported as metallic tin, hence the practical value of microscopic examination which at once detects the presence of oxide. As is well known bronzes are usually melted

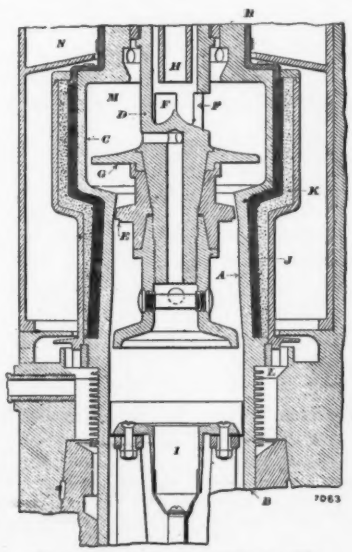


FIG. 2.—MOULD FOR FORMING LEAD PIPE.

* *The Iron Trade Review.* Vol. xxxviii., No. 17.
† Page 882, May issue.
‡ *Giesserei Zeitung*, No. 7.

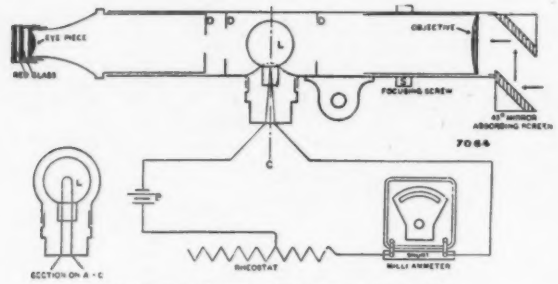


FIG. 3.—HOLBORN-KURLBAUM OPTICAL PYROMETER.

under a covering of charcoal which reduces oxides but it must be noted that this reduction only occurs when the two are in contact. The addition of phosphorus effectually reduces all oxides owing to permeation of the whole of the fluid alloy and not as in the case of charcoal superficial contact only.

*Manufacturing and Metallurgy of Ferro Vanadium**.—Under this heading Mr. J. Baxeres De Alzugaray describes his early experiments in the production of ferro vanadium. In 1898 experiments at the Silverton foundry showed that the addition of 0·5 per cent. ferro vanadium to a phosphoric pig-iron raised the maximum stress from 7·5 to 13·0 tons per sq. in. Other tests are quoted, and the following are extracted as showing the influence of vanadium on steel.

No. I.	No Vanadium.	0·1 per cent. Vanadium.
Maximum Stress tons per sq. in.	31·18	61·59
Elongation per cent. ...	16·00	23·00
No. II.	**No Vanadium.**	**0·5 per cent. Vanadium.**
Maximum Stress tons per sq. in.	35·5	53·98
Elongation per cent. ...	13·4	33·00

Analyses of five ferro vanadium alloys are given as follows:—

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
Vanadium	23·60	24·52	29·10	32·70	41·20
Iron	73·20	73·35	59·90	66·10	49·90
Aluminium	Traces.	0·77	1·00	4·60	3·70
Copper	2·80	None.	3·80	3·50	0·10
Silicon	2·40	0·09	1·30	0·70	1·35
Carbon	None.	0·33	None.	None.	None.
Phosphorus	None.	0·02	None.	None.	None.
Sulphur	None.	0·75	None.	None.	None.

Vanadium and Titanium†.—In dealing with the influence of titanium on cast-iron or steel, Dr. Goldschmidt offers some very pertinent remarks as to the limitations of chemical analysis. Thus two cast-irons are quoted, one of which has been treated with an alumino-thermic mixture giving off ferro titanium, and the other not treated. Several tests on bars of different diameters show the superiority of the treated ones, a feature not explained by the analyses. This may be due to the fact that chemical analysis as at present conducted does not show sufficiently the quality of iron or steel. Above all, dissolved oxides or gases can only be determined with difficulty, and as far as such analyses are possible, their great difficulty retards an application to ordinary analytical work. By the alumino-thermic reaction and the simultaneous introduction of small quantities of titanium, iron is freed from impurities such as gases and oxides. In such a case ordinary analysis will not show a reason for improvement in properties, although such improvement is shown in the mechanical tests.

The Effect of Impurities on the Electrical Conductivity of Copper.—Published data showing the relationship between chemical purity and electrical conductivity of copper is extremely scarce, and the greater part of the work done in this field deals with alloys carrying a considerable quantity of the impurity. In this paper Mr. Lawrence Addicks‡ gives the results of a series of researches conducted with a view to determine the amount of various elements which would lower the conductivity 3 or 4 per cent. The series were impure coppers rather than alloys. In their preparation every precaution was taken to ensure the absence of disturbing conditions and the results fairly represent the effect of the added impurity. These results are summarised in the table on the following page.

Iron and Steel.

Recent developments of the Bertrand-Thiel Process in the Manufacture of Steel.—Mr. J. H. Darby and Mr. G. Hatton give a *resumé* of recent developments

* *The Mining World*, No. 25, Vol. xxii. † *Electro-Chemical and Metallurgical Industry*, No. 6, Vol. iii.
‡ *American Institute of Mining Engineers and Mining World*, No. 24, Vol. xxii.

Element added.	First Sample.			Second Sample.			Third Sample.			Fourth Sample.		
	Amount added.	Copper %	Conductivity %.	Amount added.	Copper %	Conductivity %.	Amount added.	Copper %	Conductivity %.	Amount added.	Copper %	Conductivity %.
Aluminium	—	99·96	99·6	0·006	99·90	98·6	0·109	99·65	66·8	0·739	99·03	43·5
Antimony...	0·007	99·96	99·6	0·022	99·94	97·2	0·047	99·86	95·4	—	—	—
Arsenic ...	0·004	99·96	99·6	0·007	99·95	96·8	0·013	99·94	93·2	0·140	99·82	62·3
Bismuth ...	—	99·96	99·6	0·028	99·93	99·6	0·045	99·91	99·3	—	—	—
Cadmium ...	—	99·96	99·6	0·062	99·90	99·5	0·113	99·87	99·1	0·427	99·55	96·1
Gold	—	99·96	99·6	0·089	99·86	98·9	0·149	09·84	98·4	0·317	99·64	96·4
Iron	—	99·89	100·5	0·042	99·93	96·8	0·046	99·90	92·9	0·068	99·89	89·6
Lead	—	99·96	99·6	0·083	99·82	99·1	0·052	99·86	98·7	0·347	99·56	98·3
Oxygen ...	0·020	99·98	100·7	0·050	99·95	101·4	0·100	99·90	100·5	0·200	99·80	98·0
Phosphorus	—	99·96	99·6	0·080	—	52·3	—	—	—	—	—	—
Silicon ...	—	99·96	99·6	0·007	99·89	99·4	0·007	99·89	99·1	0·042	99·89	99·0
Silver ...	0·003	99·89	100·5	0·137	99·81	100·0	0·340	99·60	98·3	0·503	99·49	97·9
Sulphur ...	—	99·89	100·5	0·053	99·93	100·0	0·135	99·83	99·0	0·236	99·75	98·9
Tellurium	—	99·89	100·5	0·065	99·82	100·4	0·181	99·74	100·2	0·405	99·65	98·7
Tin	—	99·96	99·6	0·052	99·85	97·6	0·097	99·85	92·7	0·295	99·61	79·8
Zinc	—	99·96	99·6	0·048	99·91	98·3	0·095	99·79	96·3	—	—	—

in this process. As originally worked by Bertrand, six to seven 20-ton charges of soft steel per twenty-four hours were considered good practice for a pair of furnaces. At Brymbo, with a more highly phosphoric pig, seven similar charges per day during a week's working have been attained; whilst at the Hoesch Works, in Dortmund, ten charges have been regularly produced per day. The following return by Mr. Springorum represents a week's operation at the latter works;—

RETURN FURNISHED BY MR. SPRINGORUM FOR WEEK ENDING APRIL 8, 1905. 61 CHARGES. 1149 TONS 6 CWTS. INGOTS PRODUCED. YIELD, 104·5 PER CENT.

1905.	Number of Furnaces.	Number of Charges.	Composition of Charges.												Production. Good Material.				Consumption of Iron Ore, &c., per Metric Ton of good Steel.					
			Molten Thomas Pig Metal.		Ferro-Manganese.		Ferro-Silicon and Spiegeleisen.		Light and Plate Scrap.		Broken Moulds.		Total.		Per 24 hours.		Per Cent. of Metals Charged.	Weight of Charge.		Swedish Iron Ore.	Mill Scale.	Lime.	Limestone.	Gas Producer Coal.	Basic Material.
April.			T.	C.	T.	C.	T.	C.	T.	C.	T.	C.	T.	C.	T.	C.		T.	C.	C.	C.	C.	C.	C.	C.
3	2	10	143	19	2	8	1	14	29	18	...		177	19	186	2	104·53	18	12	3·74	1.26	1·88	0·86	5·00	1.08
4	2	11	158	1	2	11	1	6	30	6	...	..	192	4	200	17	104·50	18	5	3·48	1·18	1·86	0·86	4·64	1·10
5	2	10	143	4	2	10	1	6	34	18	2	8	184	6	192	10	104·48	19	5	3·58	0·88	1·76	0·84	4·84	1·04
6	2	10	145	4	2	10	2	13	34	12	...	..	184	19	193	6	104·52	19	6	3·40	1·14	1·76	0·82	4·82	1.04
7	2	10	144	12	2	10	4	4	25	18	...	8	177	12	185	12	104·50	18	11	3·98	1·26	1·84	0·82	5·02	1·08
8	2	10	143	15	2	14	1	4	34	4	...	16	182	13	190	19	104·55	19	2	3·36	1·10	1·78	0·84	4·88	1·04
144 hours.		61	878	15	15	3	12	7	189	16	3	12	1099	13	1149	6	104·5	18	16						
															=8 tons per hour over the whole period.									
															=4 tons per furnace hour over the whole period.									

In the case of two works employing this process and working on high phosphoric pig, it was found advisable to employ a gas heated tipping mixer in which the blast furnace metal is collected and retained for use as required. In the mixer some desulphurisation takes place, and the percentage of silicon is reduced. Figures given show the silicon to be reduced from 0·654 per cent. to 0·473 per cent., whilst sulphur falls from 0·076 per cent. to 0·040 per cent. The mixer is a costly piece of apparatus, and in order to get a better return it was decided to carry refining in it still further, only raising the temperature sufficiently high to melt the slag while adding a considerable quantity of iron ore and lime. The average temperature as determined by the Wanner

pyrometer was 1,545° C, whilst that of the secondary furnace in full heat was 1,720° C. The following table gives results obtained :—

	Average Composition of Pig Metal charged into Mixer as Primary Furnace.	Average Composition of Refined metal from Mixer as Primary Furnace ready for Secondary Furnaces	Average Composition of Final Steel from Secondary Furnace.
	Per cent.	Per cent.	Per cent.
Carbon	3·250	2·100	0·169
Silicon	0·636	0·160	0·042
Sulphur	0·053	0·043	0·028
Phosphorus	2·420	0·930	0·032
Manganese	2·400	0·780	—

In order to further test the elimination of sulphur in the primary furnace, irons were obtained containing high percentages of this element, and the following are notable instances ;—

Percentage of Sulphur in Pig Metal.	Percentage of Sulphur in Primary Metal.	Duration of 18 Ton Charge in Primary Furnace		Percentage of Carbon in Primary Furnace.
		Hours.	Minutes.	
0·308	0·060	2	45	2·2
0.209	0·070	2	15	1·6
0·240	0·078	2	40	1 8
0·370	0·100	3	0	0·9

The percentage of sulphur in the finished steel from the secondary furnace did not in any case exceed 0·05 per cent.

The Continuous Steel Process in Fixed Furnaces.—This process is based on the principle of the Talbot, with the essential difference that it can be conducted in any fixed furnace of not less than 25 tons capacity. Two or more tap holes at different levels are provided by means of which the whole or part of the contents of the furnace may be emptied at any time. In practice these tap holes can be readily arranged to give little trouble. The furnace hearths stand well and remain sound for months; as a rule only the slag line, and to a less extent the blocks, require repairs.

Details given by the author, Mr. S. Surzycki, are obtained from one 25-ton furnace at the Czenstochowa Works, which during its first campaign made 574 charges by the continuous process. Whilst still in good condition the furnace was shut down for local reasons. During this interval the ports and roof were repaired and the chambers repacked. Since its re-entry into working life the furnace has already made upwards of 690 charges, and it is hoped will keep at work until the number reaches 1,000.

The pig iron, which is of variable quality, is drawn from a 70-ton mixer. To lessen these variations the more graphitic pig is treated with iron ore which in a pulverised and heated condition is thrown into the stream as it flows from the mixer to the ladle. The ensuing reaction promotes the conversion of graphitic into combined carbon and the oxidation of silicon and manganese. This preliminary treatment hastens the working down of the charge in the furnace. In other respects the process is identical with that of the Talbot, and the final additions are made to the ladle on tapping the steel from the furnace.

The following record of a recent month's work illustrates results obtained ;—

CONSUMED.

	Tons.	Kilos per 1 ton of good ingots.
Cold pig iron ...	140·80	70·3
Molten pig iron ...	1,809·50	903·1
Ferro manganese ...	20·9	10·4
Scrap	19·8	9·9
Iron ore (Krivoi Rog)	458·1	228 6
Lime	144·3	72·0
Aluminium	0·08	——
Burnt dolomite ...	107·7	53·8
Chrome ore	2·0	1·0

PRODUCED.

Good ingots ...	2,003·7 tons.
Scrap...	41·8 ,,
Working days ...	26
Production per day...	77·07 tons.
Yield	102·72 per cent.

Analyses and tensile tests obtained from a series of twenty heats of ingot iron are given which show the material produced to be of good quality.

Concerning the Influence of Nitrogen on the Hardness of Iron.—Comparatively little is known as to the influence of nitrogen on iron and steel, and an extension of knowledge in this direction would be of wide service. To some extent Mr. O. Simmersbach reviews, in a recent issue of *Giesserei Zeitung*, the extent of present knowledge, indicating at the outset the absorption of gases by fluid metal and the retention of a certain portion on solidification. In the Bessemer process the large volume of compressed air entering the converter carries with it a considerable quantity of nitrogen which comes into direct contact with the fluid iron, On the other hand, in the Siemen's process, the metal is largely protected by the slag covering, and the conditions of the process render the absorption of nitrogen less than that of the Bessemer. A series of analyses given show that as a rule the amount of nitrogen in Bessemer metal is about twice that of similar grade Siemen's Martin steel. Further, the longer the duration of the Bessemer blow the greater the absorption of nitrogen, for the oxygen of the blast is fixed, leaving very pure nitrogen passing through fluid iron,

Dr. Wedding has stated that nitrogen unites

with pig-iron, and its presence has been proved in all classes of iron and steel. He also found that iron annealed in pure nitrogen became exceedingly hard, Stahlschmidt, by heating iron chloride in a stream of ammonia obtained an iron with an average of 11·1 per cent. nitrogen. Though by stronger heating the greater part of the nitrogen is expelled under certain conditions, sufficient remains to examine its physical effect on iron. Tholander's experiments show that the presence of 0·2 per cent. nitrogen has a decisive influence on hardness. Thus, previously, soft steel becomes glass hard by raising its content of nitrogen from 0·01 to 0.202 per cent. Similarly, soft Bessemer steel, by raising the nitrogen content to 0·294 at the surface and 0·161 per cent. in the centre, becomes equally hard and brittle. As in ordinary steels an increase in hardness is accompanied by a decrease in specific weight, so also in irons containing nitrogen an increase in nitrogen is associated with an increase in hardness or a decrease in specific weight. In addition to increasing hardness the presence of nitrogen also leads to a series of complex temperature conditions.

Blast Furnace Practice.

*Latter-day Blast Furnace Troubles.**—Since the publication of Mr. Gayley's paper desiccated air has been a subject of chief interest with blast furnace men. It is, however, recognised that development in this direction will be of comparatively slow growth. In the meantime problems daily confronting the blast furnace manager are found in the troubles incident to mechanical charging, especially when the burden carries a portion of fine ore. The advent of the skip hoist and double bell has not been followed by all the good things predicted for them. Furnaces built in the hope that their mechanical appliances would work wonders in economy have often yielded very disappointing results in cost of iron produced. When mechanical filling was first introduced emphasis was laid on the reduction of labour costs and the elimination of irregular charging. It is safe to say, however, that poor distribution has been the prime evil with which the blast furnace managers have contended in the past few years. In view of this irregularity, a fortune awaits the inventor of a simple distributing mechanism which will drop the stock into the furnace in as nearly as possible the way in which it was dumped from barrows in the days of hand filling, yet without encumbering the top of the furnace with machinery preventing ready charges in case of emergency.

Accidents due to the Asphyxiation of Blast Furnace Workmen. — Mr. B. H. Thwaite emphasises the necessity of protection from carbon mon-oxide, and gives a series of suggestions with a view to secure comparative immunity. The following table shows the effect produced by varying proportions of blast furnace gas :—

Volumetric Percentage. Proportion of Blast Furnace Gas in Air.	Ratio in Volum. of Furnace Gas to Air.	Symptoms produced after one hour's exposure.
Per cent.		
0·2	1 in 500	Giddiness.
0·35	1 in 286	Inability to walk.
0·70	1 in 143	Loss of consciousness.
1·00	1 in 100	Dangerous.

Whilst crude blast furnace gas is fairly visible and has a perceptible odour, it is, when freed from suspended matter and moisture, practically invisible and inodorous, and therefore all the more dangerous. One possible source of danger may lie in the use of blast furnace gas in gas engines, and leakages from glands or air valves will change the atmosphere in the vicinity of emission into a dangerously toxic condition. The suggested precautions practically cover all possible sources of danger. We specially note one in reference to gas engines. Gas engine exhaust pipes should terminate at a considerable altitude above the works floor, and part of the air drawn into the air tub of the blowing engine should be supplied from the engine house.

Note on the failure of an iron plate through Fatigue.—Mr. S. A. Houghton, in a short but suggestive paper, records his examination of the failure of a boiler forming part of a steam ploughing engine. This boiler was of the loco. type, and the plate which failed was in the back ring of the barrel. As a rule these plates are not subjected to fatigue stresses of importance, but in this instance a step carrying the spindle of the winding engine was rivetted to it, and consequently in working life the plate was subjected to severe panting stresses. As one end of the step was rivetted close to a longitudinal lap joint fatigue stresses were to a great extent localised, and failure actually occurred through a crack formed between the rivet holes. This crack began from inside the outer lap, and consequently was not discovered, the result being that the boiler exploded with violence.

The plates were of BB iron of the following analysis :—C. trace, Mn. trace, S. 0·023, P. 0·310 and Si. 0·180 per cent. A tensile test taken from near the fracture gave 23·8 tons per sq. in. and only 2 per cent. elongation in 1½ in., the last result being influenced by a flaw near the middle. The metal was distinctly hard, and although inferior considered as iron, its very want of ductility rendered it specially suitable for studying the effect of fatigue. From microscopical evidence the results of the action of the stresses on the structure may be summed up as follows :—(1.) Formation of slip lines indicating slipping of the crystals. (2.) Loosening of the joints between the crystals.

* *The Iron Trade Review*, Vol. xxxviii., No. 19.

(3.) Loosening of the particles of slag. In other words, the effect of fatigue stresses on this particular plate has been to form cracks, commencing, as a rule, from irregularities on the inner surface, which cracks were due to weakness in the cleavage planes of the crystals from continual slipping, and to a less degree to some loss of adhesion between the crystals.

Foundry Practice.

Air Blast for Foundry Cupola.—Mr. W. H. Carrier in a paper read before the Buffalo Foundrymen's Association discusses the operating advantages and efficiency of fans and positive blowers reaching the conclusion that the chief advantages lie with the fan. The growing use of lower pressures and larger tuyere areas, thereby obtaining better distribution of blast, is indicated. Under these conditions the advantages lie largely with the fan. A question of much importance is found in the melting capacity of various sizes of cupola under different pressures and the corresponding horse-power required for operation. This relation has been ascertained and is given in the following table. The figures on the left represent cupola diameters inside the lining and those at the top static pressure in ounces per square inch.

TABLE OF CUPOLA CAPACITIES.

—	—	10 oz.	12 oz.	14 oz.	16 oz.
30" ...	Cap.	5690	6230	6730	7200
	A. P. M.	1423	1568	1688	1800
	H. P.	7·4	9·7	12·3	15·0
35" ...	Cap.	7740	8480	9170	98 0
	A. P. M.	1935	2120	2293	2450
	H. P.	10·0	13·2	16·7	20·4
40" ...	Cap.	10120	11080	11970	12800
	A. P. M.	2530	2770	2993	3200
	H. P.	13·2	17·3	21·8	26·6
45" ...	Cap.	12810	14030	15150	16200
	A. P. M.	3203	3508	3788	4050
	H. P.	16·7	21·9	27·6	33·7
50" ...	Cap.	158:0	17320	18700	20000
	A. P. M.	3953	4330	4675	5000
	H. P.	20·6	27·0	34·0	41·6
55" ...	Cap.	19130	20960	22640	24200
	A. P. M.	4783	5240	5660	6050
	H. P.	24·9	32·7	41·2	50·3
60" ...	Cap.	22770	24940	26940	28800
	A. P. M.	5693	6235	6735	7200
	H. P.	29·6	38·9	49·0	59·9
65" ...	Cap.	26710	29270	31620	33800
	A. P. M.	6683	7318	7905	8450
	H. P.	34·8	45·7	57·5	70·3
70" ...	Cap.	30990	33950	36670	39200
	A. P. M.	7748	8488	9·68	9800
	H. P.	40·3	52·9	66·7	81·5

The first figure "Cap" gives for each size the capacity in pounds of iron per hour; the second one A. P. M. gives the cubic feet of air required per minute; and the third one H. P. gives the horse-power required for operating the fan. It should be noticed that the melting capacity increases at a much lower rate than the pressure whilst the horse-power increases very rapidly with the increase in the speed of melting. For instance a 60 inch cupola will give an average melt of 11½ tons per hour at 10 oz. pressure with 29½ horse-power. The same cupola requires 16 oz. pressure and 60 horse-power to melt 12½ tons per hour.

Moulding a Propellor.—Mr. A. M. London, in a paper read before the June Convention of the American Foundrymen's Association, describes a method of moulding a 4-blade propellor which possesses much of interest. A blade pattern, including a perfect quarter of the boss is made, as shown in the appended illustration. This pattern is bedded on an "odd side," the bottom part rammed up and lifted off, bringing with it the pattern. This is rolled over, joint

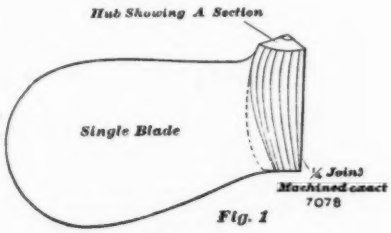


Fig. 1

MOULDING A PROPELLER.

made, top part rammed and mould finished. The pattern is replaced on its odd side, and the process repeated until four complete moulds are made. The moulds are dried, and on putting together a level bed is struck off and the first blade set by means of a plumb level on the joint of the boss. The second blade is set by using the joint of the first one as a guide and a plumb level on the opposite joint. The last one is set by size sticks which bring the hub to a perfect circle, and the quarters being true uprights, secures the blades spaced to within ¼ in. of exact quarter circle each. The boss joints are seamed up, the hub covered with a cake core, the whole mould bound down and rammed within a curbing.

REVIEWS.

I.—Les Aciers Spéciaux. By L. GUILLET, D.Sc.; with a preface by H. Le Chatelier. (Paris: Ch. Dunod.) 1904. Price, 10 francs.

II.—Notes on Assaying and Metallurgical Laboratory Experiments. By R. W. LODGE, Assistant Professor of Mining and Metallurgy; Massachusetts Institute of Technology. (New York: John Wiley & Sons; London, Chapman & Hall.) 1904. Price, 3 dols.

III.—High Temperature Measurements. By H. LE CHATELIER, Professeur de Chimie minérale au Collège de France, and O. Boudouard, D.Sc. Translated by G. K. Burgess, D.Sc. (New York: John Wiley & Sons; London, Chapman & Hall.) 2nd edition. 1904. Price, 3 dols.

I.—M. Guillet's volume — which is surely worthy of a better cover than the paper one accorded it — embodies three researches on nickel, manganese, and silicon steels, which have previously appeared in the *Bulletin de la Société d' Encouragement pour l' Industrie Nationale* or the *Revue de Métallurgie*. Special steels are a subject of keen interest, and no one has explored more in this direction than M. Guillet. As shown in our metallurgical columns, during the last eighteen months, he has studied practically the whole range of steels in which the special characteristic is induced by the presence of one element other than iron and carbon. The method of examination is familiar. Usually two series of steels are examined, one low in carbon and the other containing an average of about 0·8 per cent. in each series, an effort being made to keep the special element as the only variable. This effort is, however, not always successful, for instance the analyses of manganese steels on p. 48 vary notably in elements other than manganese. In the first or low carbon series sulphur and phosphorus are fairly constant, silicon, however, ranges from 0·163 per cent. to 1·362 per cent., three of the steels containing over 1 per cent. of this element. In the same series carbon ranges between 0·082 and 0·396 per cent., whilst in the second series this element varies between the limits of 0·700 and 0·960 per cent. Silicon contents in this series are also erratic, whilst sulphur and phosphorus are fairly constant, we note that one of the steels is reported as containing 1·011 per cent. sulphur, which in view of the other results is obviously a misprint. Of these the volume is by no means free which results in some dissimilarity between the plotted results and the tables from which they are drawn. Thus on p. 30 the elastic limit of the first steel in the table reads 39·5, whilst in the diagram it is nearer 30·5 kilos. On p. 31 the ultimate stress of a steel containing 10 per cent. nickel is 106 kilos., whilst the elastic limit is given as 166 kilos. On the tensile curve the two results are shown as coinciding at 106 kilos.

The structural changes induced by the presence of the special element nickel, manganese or silicon are carefully studied, and in most cases the photo-micrographs are excellently reproduced. The tests reported include tension, hardness and shock whilst annealing, quenching and cementation experiments are also included. With the nickel steels the influence of low temperature on the structure has been studied, and some interesting photographs are reproduced in Figs. 32 to 40, illustrating the structural changes at temperatures of 0° C.—40° C.—78° C.

A critical study of the author's three researches leaves a most favourable impression, and we cordially recommend them to any reader desirous of extending his knowledge of the influence of silicon, manganese, or nickel on steel.

II.—*Notes on Assaying.*

This work is essentially one for the student commencing a course of assaying, however, it contains much of value to those who have already completed such a course. At the outset Professor Lodge draws a distinction between "wet" and "dry" methods. "Assaying, strictly speaking, is the quantitive determination of metals in ores, furnace products, bullion, etc., by means of fire and dry reagents." "An assayer has generally to make a very large number of assays per day, whereas an equal number of chemical determinations would be out of the question." Whilst appreciating this distinction it is none the less a matter of some difficulty to draw a hard and fast line between wet and dry methods. Careful examination of the book and tests of some of the methods given, lead to the conclusion that its purpose is admirably served, and it forms for the student taking up this subject a reliable guide and laboratory companion. The last section, pages 221 to 279, deals with laboratory experiments intended for fourth year students. This section is extremely suggestive, and if conscientiously worked through will form a valuable complement to the training imparted by the earlier section.

III.—*High Temperature Measurements.*

The development of metallurgical science and industry depends very largely on temperature measurements and a knowledge of the principles underlying these measurements is essential in laboratory and in works. Naturally high temperature measurements are not confined to metallurgy, but for the present we

prefer to regard this volume, now in its second edition, solely from a metallurgical aspect. From this point of view the work is extremely valuable in that it deals clearly with underlying principles of temperature measurement and discusses fully the various types of pyrometers. For instance, the third chapter deals exhaustively with the gas thermometer, reciting some of the more important experiments conducted with it, and showing its value as a means of standardisation for the various processes used in the measurement of temperatures

The following chapter deals with calorimetric pyrometry indicating the principles involved, discussing the relative advantages of platinum, iron and nickel balls, and detailing types of calorimeters. The advantages of a calorimetric pyrometer are found in its low initial cost and in its ease of manipulation. Its inconveniences are found in the lengthy time required to take an observation, its lack of continuity, deterioration of the balls, and with a nickel ball in a temperature limit of about 1000° C. The electrical resistance pyrometer is treated in chapter V., and its use as a standard indicated, which is facilitated by the fact that the relation between the platinum thermometer scale and the gas scale has been fairly well established up to 1000° C. Chapter VI. dealing with the thermo electric pyrometer, is probably one of the best in the book, and discusses successively (1) choice of the couple, (2) choice of method of measurement, (3) sources of error, and (4) standardisation. Chapter VII. gives the laws of radiation, and is followed by heat radiation pyrometry. Optical pyrometry, in which use is made of luminous radiations only, is treated in Chapter IX., and amongst the instruments described are those of Le Chatelier, Féry and Wanner. Chapters X and XI deal respectively with expansion and contraction pyrometers; fusing point, dilution and transpiration pyrometers.

Pyrometers in conjunction with recorders are considered in Chapter XII. Records may be obtained from a pen or by means of photography. So far only three of the different pyrometers have been rendered recording: (1) The gas thermometer at a constant volume; (2) the thermo-electric pyrometer; and (3) the electrical resistance pyrometer. In practice the thermo-electric is most frequently used to take continuous records. Recorders are followed by a discussion on standardisation which imparts much timely advice, the succeeding chapter directs attention to possible avenues of further study and a complete bibliography terminates an excellent book.

This outline indicates the scope of the work, a study of which leaves many distinct impressions. Confining these impressions, we single out two of particular moment. First, the distinctive fields occupied by (1) electrical resistance; (2) thermo-electric; and (3) optical methods are very clearly indicated. Thus on p. 168:—

"Thermo electric couples, by reason of their easy use, ready calibration, small size, and of the precision of their indications are preferable to all other pyrometric methods for ordinary investigations, scientific or industrial, and, in fact, they are almost the only ones employed to-day for such uses. Their employment, however, is not to be recommended for investigations of the highest precision; preference should be given to the electric resistance pyrometer within the range that this instrument can be used . . . above 1,000° C. the thermo couple is the only form of electric pyrometer which can be used. . . In certain cases. . . a radiation or optical pyrometer may replace to advantage the thermo-electric."

The field specially open to optical pyrometry is indicated by the following extract from p. 243:—

"The optical or radiation pyrometer is peculiarly well adapted for many cases in which other methods fail, as when contact with the object whose temperature is sought cannot be made or when for any reason the pyrometer must be placed at a distance, for example, in the case of a moving body as a rail passing into the rolling mill; in the case of very high temperatures superior to those of the fusing point of platinum, as of the crucible of the blast furnace, &c."

The thermo couple necessarily involves contact and cannot therefore be applied to ascertain the temperature of moving bodies, molten metal during casting and so forth. Herein are to be found wide possibilities open to optical methods and that section of the book, pp. 171—252, devoted to this aspect is well worth careful study. A series of temperatures determined by Le Chatelier and Boudouard by means of apparatus designed by the former are given, and as showing the applicability of this form of temperature measurement we select the following (p. 221):—

SIEMENS-MARTIN FURNACE.

Flow of steel into ladle beginning	...	...	1,580° C.
" " " end	...	...	1,420° C.
" " moulds	...	...	1,450° C.

The second feature lies in standardisation, and this section of the work gives a detailed discussion of the determination of the fixed points and their reliability. A series of these points are given on p. 303, which offers good selection for calibration purposes. In determining solidification temperatures physicists do not always pay sufficient attention to melting atmospheres. The following quotations are therefore of special moment in any consideration of standardisation, p. 300. "The freezing point of silver is not a constant temperature except under very definite conditions. . . . Melted silver exposed to the air gradually absorbs oxygen which lowers the freezing point, and this latter is not a definite temperature varying with the rate of cooling, mass, and surroundings." The freezing point of copper is 1,065° C. in air, or 1,084° C. when pure.

"Values intermediate between 1,065° and 1,084° will be obtained for incomplete protection from air, the effect being due, as explained by T. W. Richards, to the formation and solution of cuprous oxide, saturation of the copper with oxide giving the point 1065°."

Copper is not usually taken as a standard, but silver is often regarded as a fixed point at 962° C. a value only applicable to pure silver melted under conditions which exclude oxidation. Attention is directed to these features in that they lend special emphasis to the metallurgical aspect of the book.

The authors are to be congratulated on their treatment of physical questions throughout and in no case have they overlooked or ignored metallurgical conditions,

Engineers' Turning. By JOSEPH HORNER, A.M.I.Mech.E. (London: Crosby Lockwood & Son, 7, Stationers' Hall Court). Price, 9*s.* net.

Mr. Horner has already achieved a high reputation as an author of several works of a practical character, which is no way likely to be diminished by the latest product of his pen—the volume before us.

The subject of turning, it is true, has been dealt with in innumerable text books, the majority of the writers of which, however, have treated the matter more from the standpoint of the amateur or all-round workman who finds the lathe a useful appliance. From the point of view of the technical student or of the machinist, such works are of small value, and a comprehensive treatise dealing with turning as practised in large shops has been much needed. This want the author has succeeded in filling, and we cordially recommend its perusal to all who are concerned with the recent practice and present development of the subject.

A feature of the volume is the important section devoted to modern Turret practice; boring is another subject which is treated fully, and the chapter on Tool Holders illustrates a large number of representative types; screw cutting and high-speed steels have received full treatment. In short, there are few matters of importance which have not been touched upon. Great care has been bestowed on the illustrations, and the book, which is of a convenient size, is excellently printed.

The Compound Engine. By W. J. TENNANT, A.M.I.Mech.E. (London: Percival, Marshall & Co., 26-29, Poppin's Court, E.C.). Price, 2*s.* 6*d.* net.

An excellent introductory manual, intended for the use of elementary students. A chapter calling for particular attention is that devoted to the working out in complete detail an example of Prof. Unwin's method of producing an indicator diagram for the first and succeeding cylinders of a compound engine.

Modern Electric Practice. Vol. VI. Edited by MAGNUS MACLEAN, M.A., D.Sc. (London: The Gresham Publishing Co., 34, Southampton Street, Strand, W.C.). Price, 9*s.* net.

This volume contains contributions on Telegraphy by A. C. Booth; Telephony by Dane Sinclair, M.I.E.E.; Electricity in Mining by D. Burns, M.I.E.E.; Electromedical Appliances by D. Turner, M.D.; and Modern Electrical Appliances employed in the Operation of Railways, by W. E. Langdon, all of which maintain the high character of those in the preceding volumes. In Mr. Langdon's contribution will be found a very complete description of Messrs. Webb and Thompson's electrically operated signalling system, of Lyke's electro-mechanical system now being installed at St. Enoch's Station, Glasgow; and of the systems employed on the Liverpool Overhead Electric and the Waterloo and City Railways. This, the final volume, is provided with a complete and valuable index to the whole series.

Structural and Field Geology. By JAMES GEIKIE, L.L.D., D.C.L., F.R.S. (Edinburgh: Oliver and Boyd; London: Gurney and Jackson, 10, Paternoster Row). Price, 12*s.* 6*d.* net.

No civil engineer will deny the value of a systematic study of structural geology. True, there may be many matters involved in such a study which are of no special importance to him or bearing directly on his own professional study. Nevertheless, no one will doubt the wisdom of understanding the method of observation employed in field geology, especially geological surveying and map construction. There is a conspicuous absence of a good text book written up to the requirements of the civil engineer especially, and he has therefore, in his reading, to distinguish between matters of general interest and that which is of special importance to him. Professor Geikie's work proves extremely valuable in this respect, as, to help in this discrimination, two sizes of type have been employed—the smaller being commonly reserved for details mainly in the domain of pure science.

A fine series of plates, many of them from unpublished photographs taken from H.M. Geological survey, accompany the volume, and give a special interest to a work which no civil or mining engineer will regret having in his possession.

The Mechanical Engineering of Collieries. By T. CAMPBELL FUTERS. Vol. I. (London: The Chichester Press, 30 and 31, Furnival Street, E.C.). Price, 7*s.* 6*d.*

This is the first volume of an entirely new work on the mechanical engineering of collieries, specially written for the *Colliery Guardian*. In view of the stress which has been laid upon

the necessity of employing the most perfect machinery in the obtaining of coal—a contention amply endorsed by the Royal Commission on coal supplies—the appearance of this volume has been particularly well timed, and will be appreciated by all colliery managers and engineers. In no branch of industry, perhaps, have mechanical arrangements within the past twenty years undergone so much change, and the application of electricity has further added to the complexity and responsibility of the duties attaching to the positions of management. Hence Mr. Suter's work will be doubly appreciated. This volume deals with boring, sinking, surface arrangements, headgears, shafts. The other portions of the work are now appearing weekly in the columns of our contemporary, and will be published in book form as soon as completed.

Modern Engines and Power Generators. By RANKIN KENNEDY, C.E. Vol. V. (London: The Caxton Publishing Co., 84-86, Chancery Lane, E.C.). Price, 9*s.* net.

This, the fifth volume of the series, maintains the standard of value and usefulness possessed by its predecessors, and has for its subject matter high-speed enclosed engines; marine engines; turbines and locomotives—steam, electric, and oil.

Petrol Motors and Motor Cars. By T. HYLER WHITE, A.M.I.Mech.E. (London: Longman's, Green & Co., 39, Paternoster Row, E.C.). Price, 4*s.* 6*d.* net.

Among the many books recently issued dealing with internal combustion motors, we have failed to discover one written entirely from the designer's point of view. Draughtsmen will therefore welcome a book containing reliable information and formulæ presented in a concise form, and by which the work of designing a motor and the various other parts of a motor vehicle, will be reduced to a minimum.

Mr. White has succeeded in a work the utility of which will be appreciated by those to whom it is particularly addressed. Many useful tables have been collected in the appendix, while the index to formulæ is a feature which might with advantage be copied in many other technical works, saving, as it does, the necessity of wading through pages of descriptive matter to find what one wants.

Constructional Steelwork. By A. W. FARNSWORTH, A.M.I.Mech.E. (London: Charles Griffin & Co., Ltd., Exeter Street). Price, 7*s.* 6*d.*

Recognising the difficulty arising from lack of practical knowledge experienced by many to whom it falls to design and superintend structural erections, the author has attempted to give such an indication of what they should seek to embody in their creations, and more particularly of the essentials and modes of manufacture. The book is divided into two parts, the first—the outcome of a series of articles in *The Engineer*—treating of various phases of practical designing; the second dealing with practical shop work. Both sections are well done, and the chapter on Economy in particular can be studied with advantage by those even for whom the work is not directly intended. Other chapters calling for particular mention are those devoted to Inspection, and Estimating, and the work, if only for the adequate account it gives of the present methods and tools of manufacture, is well worth the attention of designers generally.

Elementary Steam Engineering. By H. W. METCALFE, R.N. (London: Longmans, Green & Co., 39, Paternoster Row, E.C.). Price, 7*s.* 6*d.* net.

This is a text book intended for very young students such as cadets at Osborne, who know little or nothing either of physics or mechanics, and would, therefore, be unable to grasp the meaning of the ordinary text book.

As a preliminary to such, the present work is well suited. Chapter I. is devoted to Engineering Sketching; Chapter II. to the elements of Propulsion, Screw Propeller, Thrust and Shafting. The succeeding chapters deal with the Steam Engine, and the last with Materials used in the construction of machinery generally.

In this section is presented every month a list of the principal contents of the leading organs of the technical press and of the proceedings of learned societies throughout Great Britain, the Continent, and America. The following is an alphabetically-arranged list of the publications regularly reviewed, together with the place of publication and price.

American Engineer and Railroad Journal, 140, *Nassau Street, New York* ... ... 20 cts.
American Machinery, 9-15, *Murray Street, New York* ... ... 20 cts.
American Machinist, 218, *William Street, New York* ... ... 4d.
Annales des l'Association des Ingenieurs sortie de Gand, *Rue Longue du Marais*, 15, *Ghent*... 2 frs. 30 c.
Association of Engineering Societies, Philadelphia, *Philadelphia* ... ... 30 cts.
Australian Mining Standard, 31, *Queen Street, Melbourne* ... ... 6d.
Automobile Club Journal, 119, *Piccadilly, W.* 6d.
Automotor Journal, 44, *St. Martin's Lane, W.C.* 3d.
The Autocar, *Coventry* ... ... 3d.

Beton und Eisen, *Kortorung*, 14, *Vienna I.* ... 2 marks
British Clayworker, 43, *Essex Street, W.C.* ... 6d.
Bulletin La Société International des Electriciens, 12 & 14, *Rue de Stael, Paris* ... 2 fr. 50 c.
Canadian Engineer, 62, *Church Street, Toronto* 10 cts.
Centralblatt für Accumulatoren, *Gross Lichterfelde-West, Bellevuestrasse*, 40, *Berlin* ... 3 mks. 50 pf. per qt.
Colliery Guardian, 30 & 31, *Furnival Street, Holborn, E.C.* ... ... 5d.
Compte Rendu des Travaux de la Société des Ingenieures Civils de France, 9, *Rue Blanche, Paris* ... ... —
Der Mechaniker, 113, *Potsdamerstrasse, Berlin, W.* 35 ... ... 40 pf.
Dingler's Polytechnic Journal, *Berlin* .. ... { 3 mos. / 6 mrks.
L'Echo des Mines et de la Metallurgie, *Paris*... 45 fr. p.a.
L'Eclairage Electrique, 40, *Rue des Ecoles, Paris* ... ... 1 fr. 50 c.
Electrical Engineer, 139, *Salisbury Court, E.C.* 3d.
Electrical Review, N.Y., 41, *Park Row, New York, U.S.A.* ... ... 10 cts.
Electrical Times, 8, *Breams Buildings, Chancery Lane, E.C.* ... ... 2d.
Electrical World and Engineer, 120, *Liberty Street, New York*... ... ... 10 cts.
The Electrician, 1/3, *Salisbury Court, E.C.* ... 6d.
L'Electricien, 18, *Rue des Fosses, St. Jacques, Paris* ... ... 50 cts.
Electricity, 36, *Maiden Lane, W.C.* ... ... 1d.
Electricity, 136, *Liberty Street, New York* ... 10 cts.
Der Electro Techniker, *Hengasse*, 62, *Vienna*... 60 pfs.
Elektrische Bahnen U. Betriebe, 8, *Gluckstrasse, Munich* ... ... 16 mks. p.a.
Elektrotechnische Rundschau, *Heiderstr*, 104, *Dusseldorf*, ... 6 mks. 6 mos.
Elektroteknisk Tidsskrift, *Copenhagen* ... ... 12 öre. 4 kr. for 6 mos.
Elektroteknisk Tidskrift, *Christiana* ... ... 6 mos.
Elektrotechnische Zeitschrift, *Monbiitonplatz*, 3, *Berlin*, N. 24 ... ... 70 pf.
L'Elettricista, *Vi Cavour*, 222/226, *Rome* ... 25 cts.
L'Elettricita, *Via Boccaccio*, 5, *Milan* ... ... 50 cts.
La Energia Electrica, *Plaza de Isabel* 11, *num.* 5, *Madrid* ... ... 1 peseta
The Engineer, 33, *Norfolk Street, W.C.*... ... 6d.
Engineering, 35/36, *Bedford Street, W.C.* ... 6d.
Engineering and Mining Journal, 253, *Broadway, New York* ... ... per ann.
Engineering Magazine, 222, *Strand, W.C.* ... 1/-
Engineering News, 220, *Broadway, New York* 15 cts.
Engineering Record, 114, *Liberty Street, New York* ... ... 12 cts.
The Foundry, *Cleveland, Ohio, U.S.A.*... ... 15 cts.

Gas World, 3, *Ludgate Circus Buildings, E.C.* 3d.
Le Gaz, 12, *Rue Fountaine, Paris* ... ... 1 fr.
Le Genie Civil, 6, *Rue de la Chaussee d'Antin, Paris* ... ... 1 fr.
Giesserei-Zeitung, *Jerusalemer Strasse*, 46/47, *Berlin, S.W.* ... ... 40 pf.
Gluckauf, *Essen, A. D., Ruhr, Germany* 1 mk. 25 pf.

La Houille Blanche, *Grande-Rue*, 23, *Grenoble* 1 fr. 25 c.

Ice and Cold Storage, 89, *Farringdon St., E.C.* 6d.
L'Industrie Electrique ... ... 1 fr.
Iron Trade Review, *Cleveland, Ohio* ... ... 4 dols. 50 c. p.a.
Iron and Coal Trades' Review, 165, *Strand, W.C.* 6d.
Iron and Steel Magazine, 446, *Tremount Street, Boston* ... ... 50 cts.
Iron and Steel Trades' Journal, 4, *Suffolk Lane, Cannon Street, E.C.* ... ... 3d.

Journal American Society of Naval Engineers, *Washington* ... ... 5 dols. p.a.
Journal of the Association of Engineering Societies, *Philadelphia, Pa.* ... ... —
Journal of the Chemical, Metallurgical and Mining Society, *Johannesburg, S.A.* ... 2/-
Journal of Gas Lighting, 11, *Bolt Court, Fleet Street, E.C.* ... ... 6d.
Journal of the Franklin Institute, *Philadelphia, U.S.A.* ... ... 30 cts.
Journal of the Institution of Electrical Engineers, 92, *Victoria Street, S.W.* Single copies vary 1/6-7/6
Journal of the Iron and Steel Institute, 28, *Victoria Street, S.W.* ... ... 16/- per vol. "2 annually
Journal of the Society of Arts, *John Street, Adelphi, W.C.* ... ... 6d.
Journal of the Western Society of Engineers, *Chicago, U.S.A.*... ... ... 50 cts.

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